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ACTIVATED CARBON AS A FERTILIZER

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On different occasions papers have appeared in the literature discussing the use of carbon as a fertilizer. These papers have dealt with such substances as raw peat, ammoniated peat, humic acid, ammoniated humates, raw coal and activated coal. Crowther and Brenchley (1) make the following comments on this subject.

"The desire to discover new outlets for coals of low industrial value has led to much discussion in the technical press of Central Europe on the possible value of brown coal and of certain humic materials prepared by the gentle oxidation of coal. It is possible to produce humic acids which give readily soluble ammonium or potassium salts, and it would appear that such products are more suitable for direct tests on the possible fertilizer value of humic materials than any of the cruder materials previously available. It has been claimed that there is already sufficient evidence to show that manuring with coal will become important in the near future. Unfortunately it would appear that many of the experiments have been made by workers who are more familiar with coal technology than with agricultural experimentation or soil chemistry. The statement of results sometimes suggest propaganda rather than research, and the discussions of the possible mechanism of the crop increases observed are unconvincing. They mention among others the stimulation of the growth of Lemna in water cultures, the improvement in physical properties, the direct assimilation of carbon compounds by plants, and the steady liberation of carbon dioxide and available nitrogen. Apart however from the hypothetical stimulation of crop growth there is the possibility that a humic acid from coal might provide a suitable carrier for ammonia with certain advantages over ammonium sulphate, or might be used with advantage as a drier in mixing compound fertilizers."

The results of their experiments led to the following conclusion: Ammoniated humates prepared from coal were no more beneficial than a similar amount of ammonium fertilizer.

Kissel (2) reports satisfactory results from the use of coal as a fertilizer. Lemmermann's (3) results were in some instances not promising, but on the other hand showed some promise, especially with the activated humus, and Lieske (4) is an ardent advocate of the use of coal and coal products as fertilizers.

Alberta is well supplied with the softer varieties of coal which are easily mined, and as the result of development propaganda we were induced to carry out experiments with activated coal products in 1933 and 1934.

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At the request of the Northwestern Utilities Company of Edmonton the Belgium manufacturer of coal fertilizer products supplied us with one of their solid fertilizer products "Phoska-Elsyn". They list the analyses of this product as follows:

7%	organic matter
15%	P_2O_5—5% citric-soluble
1.5%	MgO
0.5%	N
18%	CaO

We found that this product contained approximately 16% total P_2O_5, none of which was water soluble, but a considerable proportion was soluble in .002N H_2SO_4. There was present also 1.88% SO_4.

The Sobelsyn company, manufacturing this and other products, makes many claims for their superiority as fertilizers. The supposedly superior quality of the Sobelsyn fertilizers is explained by the theory that they act as catalyzers, and this causes a stimulated change in the plant mechanism of growth and a decided increase in fixation of gaseous nitrogen of the air by mirco-organisms and by higher plants. This theory is advocated by Professor Rocasolano and a small group of supporting scientists, among whom Lieske is an ardent advocate.

Rocasolano (5) specifically mentions manganese and iron as chief catalyzers, and according to reports has estimated that as much as 530 pounds of nitrogen per acre may be fixed by the use of these catalytic fertilizers.

The statement of claims for these products is expressed in the following quotation from reports issued by the manufacturer of these fertilizers. ". . . . the explanation of the intense and rapid action of Elsyn fertilizers whose basis is colloidal carbon obtained from electrolysis, and whose action on the phenomena of plant nutrition is explained by catalytic effect of the catalyzer for which it forms the support."

From the above statement of analyses of the "phoska-elsyn" it may be seen that, aside from any catalytic action it may have, this product may be considered as a low grade fertilizer in so far as it carries phosphorus, small quantities of potassium and sulphur. Previous experiments (6, 7) on the gray wooded soils have shown that both legumes and cereals gave some response to phosphorus and potash, the legumes decided response to sulphur and nitrogen, and the cereals decided response to nitrogen. Legumes and cereals on the black soils showed decided responses to phosphorus, and some response to nitrogen and potash. Thus the phoska-elsyn fertilizer should show some response on these soils as a direct result of its application apart from any catalytic effect it may have.

It is stated that this fertilizer can be prepared more cheaply than ordinary fertilizers and that it is just as efficient pound for pound; furthermore that these catalytic fertilizers exert a residual effect and such effects may be seen for two and three years following their application.

With the above statements before us we formulated plans for comparisons whereby the following fertilizers, ammonium sulphate, ammonium phosphate 16–20, ammonium phosphate 10–48, single superphosphate, triple superphosphate, gypsum, sulphur, potash and phoska-elsyn were applied to different crops at approximately similar rates.

The fertilizer trials were conducted at five different points; Breton, Warburg, Fallis, Spruce Grove and Edmonton. They consisted of six different lay outs, four of which were on the gray wooded soils and two on the black soils. Two of the lay outs were at Fallis. The lay outs at the different points were not identical, but did give a fairly comprehensive comparison for the above mentioned fertilizers. The fertilizers were applied to some of the plots only in 1933 whereas other plots received fertilizers both in 1933 and 1934. This afforded excellent opportunity to study both direct and residual effects upon the crops.

The crops used in these experiments consisted of wheat, oats, barley, alsike clover, red clover (Altaswede) and alfalfa. Some of the clovers were in the second crop year, some in the first crop year and some seeded in 1933. Yields were not taken from the clovers during the season of seeding. Wheat and barley were the only crops grown on the black soils, but all crops were grown on the gray soils.

PLAN OF EXPERIMENTS

There were 107 plots (including checks) used in these experiments and since they consisted of six different lay outs and involved six different crops the details of yields will be omitted from this paper. Only a brief outline of the plan and results for each field is given, but at a later point a summarized tabulation of the yields will be found. The following plans show the arrangement of the plots at the various locations.

BRETON PLOTS—GRAY WOODED SOIL

Plot 0	Check	
Plot 1	Ammonium sulphate	120 lbs. per acre
Plot 2	Ammonium phopshate 16–20	100 lbs. per acre
Plot 3	Single superphosphate 18%	100 lbs. per acre
Plot 4	Triple superphosphate 45%	100 lbs. per acre
Plot 5	Phoska-elsyn	100 lbs. per acre
Plot 6	Phoska-elsyn	200 lbs. per acre
Plot 7	KCl	60 lbs. per acre
Plot 8	Check	
Plot 9	Gypsum	100 lbs. per acre

The plots extended across three different crops in 1933, red clover (Altaswede), barley nursing red clover, alsike clover, whereas the crops for 1934 were red clover, red clover alsike clover. In 1933 the phoska-elsyn fertilizer gave positive and appreciable increases (1390 pounds for red clover and 743 pounds for alsike) on the clovers but no significant increase on the barley. However the increases from ammonium sulphate and ammonium phosphate were about 2900 pounds on the red clover, 1750 pounds on the alsike and 6.5 bushels on the barley. In 1934 the residual increases from phoska-elsyn were about 450 pounds of clover as against 2100 pounds for ammonium phosphate and 2950 pounds for ammonium sulphate.

Of the six different lay outs in which phoska-elsyn was used its greatest response was on the Breton plots. However in view of the claims made for it this fertilizer was disappointing in the above experiments when compared with such fertilizers as ammonium sulphate and ammonium phosphate.

WARBURG PLOTS—GRAY WOODED SOIL

Plot 1	Check	
Plot 2	Triple superphosphate 45%	100 lbs. per acre
Plot 3	Single superphosphate 18%	100 lbs. per acre
Plot 4	Phoska-elsyn	125 lbs. per acre
Plot 5	Check	
Plot 6	Ammonium phosphate 16–20	100 lbs. per acre
Plot 7	Phoska-elsyn	125 lbs. per acre
Plot 8	Check	
Plot 9	Ammonium sulphate	100 lbs. per acre
Plot 10	Ammonium phosphate 16–20	100 lbs. per acre
Plot 11	Gypsum	100 lbs. per acre

The plots extended across three different crops in 1933, alfalfa, alsike clover, wheat nursing alsike, and alfalfa and alsike for 1934. The phoska-elsyn showed no direct effect in 1933 either on the wheat or clovers, whereas ammonium phosphate directly increased the yield of wheat by about 9 bushels. The direct effect of phoska-elsyn in 1934, after two years application, was 800 pounds of hay for alfalfa and 660 pounds for alsike, whereas the direct effect of ammonium phosphate was about 2600 pounds for alfalfa and 4000 pounds for alsike. The residual effect of phoska-elsyn was 375 pounds for alfalfa and −265 pounds for alsike, whereas the residual effect from ammonium phosphate was about 1400 pounds for alfalfa and 3100 pounds for alsike.

FALLIS PLOTS—GRAY WOODED SOIL

Plot 1	Check	
Plot 2	Phoska-elsyn	125 lbs. per acre
Plot 3	Ammonium phosphate 16–20	100 lbs. per acre
Plot 4	Ammonium sulphate	100 lbs. per acre
Plot 5	Check	
Plot 6	Gypsum	100 lbs. per acre
Plot 7	Single superphosphate 18%	100 lbs. per acre
Plot 8	Triple superphosphate 45%	100 lbs. per acre
Plot 9	Check	
Plot 10	Sulphur	100 lbs. per acre

The only crop grown on these plots during the two years was alsike clover. The phoska-elsyn showed 387 pounds direct increase and no residual effect, whereas the other fertilizers showed direct increases varying from 1217 pounds for triple superphosphate to 2767 pounds for ammonium phosphate, and residual increases varying from 750 pounds to 2915 pounds for the other fertilizers.

FALLIS PLOTS—GRAY WOODED SOIL

Plot 1	West Check	
Plot 2	Ammonium sulphate	100 lbs. per acre
Plot 3	Ammonium phosphate 16–20	100 lbs. per acre
Plot 4	Phoska-elsyn	125 lbs. per acre
Plot 5	East check	

Oats were grown on these plots in 1933.

Phoska-elsyn gave about 3 bushels increase, whereas the other fertilizers gave about 18 bushel increases. The former fertilizer was very disappointing in comparison with the other fertilizers on the Fallis plots, both for the grain and clover crops.

Spruce Grove—black soil

Plot 0	Ammonium phosphate 10–48	35 lbs. per acre
Plot 1	Phoska-elsyn	70 lbs. per acre
Plot 2	Check	
Plot 3	Ammonium phosphate 10–48	35 lbs. per acre
Plot 4	Check	
Plot 5	Phoska-elsyn	70 lbs. per acre
Plot 6	Ammonium phosphate 10–48	35 lbs. per acre
Plot 7	Check	
Plot 8	Ammonium phosphate 16–20	45 lbs. per acre
Plot 9	Ammonium phosphate 10–48	35 lbs. per acre

Wheat was grown on these plots both years. The phoska-elsyn showed no significant effects either direct or residual, whereas the ammonium phosphates gave from 5 to 9 bushel direct increases with no significant residual increases.

Edmonton—black soil

Plots 19, 25, 31, 37	Checks	
Plots 20, 26, 32, 38	Phoska-elsyn	120 lbs. per acre
Plots 21, 27, 33	Ammonium sulphate	60 lbs. per acre
Plots 22, 28, 34	Triple superphosphate	100 lbs. per acre
Plots 23, 29, 35	Ammonium phosphate 10–48	100 lbs. per acre
Plots 24, 30, 36	Ammonium phosphate KCl	100 lbs. per acre 50 lbs. per acre

Wheat was grown in 1933 and barley in 1934. The phoska-elsyn and ammonium sulphate fertilizers failed to show any response in the growing crop and gave no significant increases either direct or residual, whereas the other fertilizers gave decided direct increases on both crops.

SUMMARIZED STATEMENT OF YIELDS

From the above plans showing the rates and kinds of fertilizers applied, together with the crops grown, it will be remembered that the arrangement of plots and the kinds of fertilizers applied were not identical for the various lay outs. However, the rates of fertilizer application in most cases were approximately 100 pounds per acre. The fertilizer was applied as a top dressing in all cases for the legumes and for the grains on the gray soils, whereas it was drilled in with the seed on the black soils.

Legumes were grown at three different locations; Breton, Warburg, and Fallis for the years 1933 and 1934. The average increases in pounds per acre of cured hay for each fertilizer on the three crops; alfalfa, red clover, and alsike clover, are shown in Table 1.

Table 1.—Average direct and residual increases for fertilizers on alfalfa, red clover and alsike clover expressed as pounds cured hay per acre for gray wooded soils. (Data represent increases over check plots).

Fertilizer	Direct increases	Residual increases
Phoska-elsyn 16% P_2O_5	868	149
Triple superphosphate 45%	1103	143
Single superphosphate 18%	1750	851
Ammonium phosphate 16–20	2740	2040
Ammonium sulphate	2726	2435
Gypsum	2232	2350
Sulphur	1832	2915

In general each figure showing the direct increase is the result of the averages of from six to nine individual trials. The figures showing the residual increases are averages of about half this number of trials. The only exception to the above statement is in the case of the sulphur treatment where data from only two plots are available. The average yield from the check plots for these three crops is 1244 pounds per acre. The approximate yields from any of the above fertilized plots can be obtained by adding this figure to those shown in the above table. The yields from the alfalfa checks were slightly lower than the above figure. The yields from the alsike were almost identical to that of the above figure and the yields from the red clover were slightly higher than the above figures.

Only one cutting from each of the above crops was taken each year. The alsike and the red clovers are one cut crops under our conditions. Alfalfa is a two cut crop, but we were unable to get a second cutting in either year.

The average direct increase (Table 1) from the phoska-elsyn was 868 pounds of hay as compared with 1103 pounds for triple superphosphate, 1750 pounds for single superphosphate, 1832 pounds for sulphur, 2232 pounds for gypsum, and about 2700 pounds each for ammonium sulphate and ammonium phosphate 16–20. There was a small but insignificant residual increase each for phoska-elsyn and triple superphosphate, 851 pounds residual for single superphosphate, and from 1 ton to $1\frac{1}{2}$ tons for each of the other fertilizers. The residual increase was of the same order as the direct increase for the ammonium sulphate, ammonium phosphate 16-20, gypsum, and sulphur fertilizers.

By adding the direct and residual increases the following comparison is shown; phoska-elsyn 1017 pounds, triple superphosphate 1246 pounds, single superphosphate 2601 pounds, ammonium phosphate 4780 pounds, ammonium sulphate 5161 pounds, gypsum 4582 pounds, sulphur 4747 pounds. Such increases of hay, ranging from $\frac{1}{2}$ ton for phoska-elsyn to $2\frac{1}{2}$ tons for ammonium sulphate are noteworthy when it is considered that in most cases only about 100 pounds of fertilizer were applied. The increases (direct plus residual) from such fertilizers as ammonium phosphate, ammonium sulphate, gypsum and sulphur were more than four times as great as from the phoska-elsyn. It should be mentioned that the yields from 1 acre fertilized with ammonium sulphate or ammonium phosphate produced as much clover hay as 3 acres of unfertilized land, while 1 acre fertilized with phoska-elsyn was only as good as 1.4 acres unfertilized.

The greatest response from the phoska-elsyn fertilizer was on the Breton field (see Figure 1) where the direct increase was about 1400 pounds of red clover hay, but even here the results were disappointing in comparison with such fertilizers as ammonium sulphate and ammonium phosphate 16-20 where the increases were over 2800 pounds.

From the data in Table 1 it will be seen that the phoska-elsyn gave the smallest increases of any of the fertilizers. In about $\frac{1}{3}$ of the trials at three different locations and with three different legumes the direct effect of this fertilizer was so small that it was difficult to observe in the field, and in most cases it was impossible to observe any residual effect from this fertilizer. The claims of the manufacturer are that this fertilizer shows residual effects upon the late fall growth and extends over a period of two to three years. This statement was not substantiated in our trials.

1 2 3 4 5 6 7 0

FIGURE 1. Red clover (Altaswede), Breton, 1933.

Each bundle harvested from 1 square yard. Plots 1 and 2 were taller than the photo indicates, as they were badly lodged.

Plot	Treatment	Yield, lbs.	Plot	Treatment	Yield, lbs.
1	Ammonium sulphate	5200	5	Phoska-elsyn 100 lbs.	3770
2	Ammonium phosphate	4860	6	Phoska-elsyn 200 lbs.	3325
3	Single superphosphate	3700	7	KCl	2655
4	Triple superphosphate	3480	0	None	2142

31 32 33 34 35 36

FIGURE 2. Wheat on black soil, Edmonton, 1933.

Each bundle represents 4 square yards. Note the 3 bundles on the left appear similar and much inferior to the 3 on the right.

Plot	Treatment	Average yield of 4 plots	Plot	Treatment	Average yield of 4 plots
31	Checks	39.8	34	Triple superphosphate	48.3
32	Phoska-elsyn	39.9	35	Ammonium phosphate 10–48	50.1
33	Ammonium sulphate	42.5	36	Ammonium phosphate + KCl	48.4

The increases in grain yields resulting from the application of the various fertilizers are shown in Table 2.

TABLE 2.—SUMMARY OF INCREASES FOR WHEAT, BARLEY, AND OATS ON GRAY WOODED SOILS AND BLACK SOILS (RESULTS EXPRESSED AS AVERAGE BUSHELS INCREASE OVER CHECK PLOTS)*

Fertilizer	Gray wooded soils			Black soils		
	Barley at Breton after oats	Wheat at Warburg after summer-fallow	Oats at Fallis after summer-fallow	Wheat at Edmonton after wheat	Barley at Edmonton after wheat	Wheat at Spruce Grove after wheat
Phoska-elsyn	1.5	0.0	3.0	0.1	1.2	1.3
Triple superphosphate	−2.3	6.1	—	8.5	2.0	—
Single superphosphate	2.5	5.9	—	—	—	—
Ammonium phosphate 16–20	6.5	8.7	18.4	—	—	6.5
Ammonium sulphate	6.5	—	17.4	2.5	1.4	—
Ammonium phosphate 10–48	—	—	—	10.3	4.4	6.9
Ammonium phosphate 10–48, KCl	—	—	—	8.6	4.9	—

* The yields for the check plots were as follows: barley at Breton 26.0, wheat at Warburg 20.3, oats at Fallis 73.2, wheat at Edmonton 39.8, barley at Edmonton 18.8, and wheat at Spruce Grove 20.5 bushels respectively.

Wheat, oats, and barley were grown on the gray wooded soils but only wheat and barley on the black soils. Increases of the order of two bushels per acre or less are considered as having no significance unless they are accompanied by visible differences during the growth in the field, such as earlier heading, taller plants, or earlier ripening. In no instance was it possible to distinguish any increase in the growing grain crops for the phoska-elsyn fertilizer and the yield data failed to show, with one exception, any significant increase for this fertilizer. The appearance of the crop on one of the fields may be noted by referring to Figure 2 where the relative yields from adjacent plots on the experimental field at Edmonton are shown. From this figure it may be seen that the first three plots, namely check, phoska-elsyn, and ammonium sulphate are similar in appearance and yield, whereas the remaining plots, triple superphosphate, ammonium phosphate, and ammonium phosphate plus potash are much superior. The increases for the latter three plots were of the order of 8.5 to 10.3 bushels. The appearance of the barley crop on these same plots in 1934 presented a similar picture but owing to severe frost damage the yields were only about half normal. The plots fertilized with phosphorus in any form except phoska-elsyn were earlier and much superior in straw yields to the other three plots.

The advocates of phoska-elsyn as an activated carbon or catalytic fertilizer mention astonishing results under European conditions when it is used for the production of flowers, especially, but also acclaim t as a superior fertilizer for such crops as hay, pastures, tobacco, potatoes, etc. They mention that large quantities of amtospheric nitrogen may be fixed and utilized by plants as the result of using this fertilizer, and that its influence is residual extending at times for a period of two to three years. In our experiments these claims were not substantiated. If the catalytic fertilizer, phoska-elsyn, fixed nitrogen as claimed, then it should have shown

distinctly on the grain crops grown on the gray wooded soils. This it failed to do in our experiments. On the other hand since it contained 16% P_2O_5 it might reasonably be expected to show significant increases for the grain crops on the black soils. Here again the results were disappointing. On both soils the phoska-elsyn had but little, if any value, as a fertilizer for grain crops.

SUMMARY

Fertilizer trials comparing an activated carbon product, phoska-elsyn, with ammonium sulphate, two ammonium phosphates, triple superphosphate, potash, gypsum, and sulphur were conducted at three different locations on the gray wooded soils and at two locations on the black soils.

These trials extended over two years and included the following crops: alfalfa, red clover (Altaswede), alsike clover, wheat, barley, and oats.

The average direct increases of clover hay for the phoska-elsyn was about 870 pounds per acre, but in about one-third of the trials no significant increase could be observed in the growing crop. On the other hand such fertilizers as ammonium sulphate, ammonium phosphate, gypsum, and sulphur invariably showed decided direct increases, varying from about 1 ton to 1½ tons. The residual increases from the phoska-elsyn were very small and could not be observed in the growing crop, whereas the residual increases from the other fertilizers above mentioned varied from about 1 ton to 1½ tons. The combined direct and residual increases from phoska-elsyn were about ½ ton as compared with from 2 tons to 2½ tons for all other fertilizers except triple superphosphate.

In no instance were we able to distinguish any increase in the growing grain crops (wheat, barley, and oats) for phoska-elsyn either on the gray soils or on the black soils, whereas nitrogen fertilizers showed decided increases on the gray soils and phosphorus showed decided increases on the black soils. There was no residual effect for this fertilizer on the grain crops.

In our experiments phoska-elsyn was inferior to any of the fertilizers with which it was compared and in a fair proportion of the trials gave no significant increases. It failed to sbustantiate the claims made for it.

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Résumé

La valeur fertilisante du carbone activé—F. A. Wyatt et Al. Leahey, Université de l'Alberta, Edmonton, Alberta.

Il a été conduit des essais d'engrais chimiques comportant une comparaison d'un produit de carbone activé, le "phoska-elsyn", et de sulfate d'ammonium, deux phosphates d'ammonium, du superphosphate triple, de la potasse, du plâtre et du soufre, à trois endroits différents sur sols gris boisés et à deux endroits sur sols noirs. Ces essais qui ont duré deux ans portaient sur les récoltes suivantes: luzerne, trèfle rouge (altaswede), trèfle d'alsike, blé, orge et avoine. L'augmentation moyenne directe dans la récolte de foin de trèfle, après l'application de phoska-elsyn, a été d'environ 870 livres par acre, mais dans un tiers des essais environ aucune augmentation significative n'a pu être observée dans la récolte sur pied. D'autre part, certains engrais comme le sulfate d'ammonium, le phosphate d'ammonium, le plâtre et le soufre, accusaient invariablement de fortes augmentations directes, variant d'environ 1 tonne à $1\frac{1}{2}$ tonne. Les augmentations subséquentes résultant du phoska-elsyn étaient très faibles et n'ont pu être discernées dans la récolte sur pied, tandis que les augmentations subséquentes résultant des autres engrais ci-haut mentionnés variaient d'environ 1 tonne à $1\frac{1}{2}$ tonne. Les augmentations combinées, directes et subséquentes, de phoska-elsyn étaient d'environ une demi-tonne contre 2 à $2\frac{1}{2}$ tonnes pour tous les autres engrais, à l'exception du superphosphate triple. Aucune augmentation n'a pu être distinguée dans la récolte de grain sur pied (blé, orge et avoine) après l'application du phoska-elsyn, pas plus sur les sols gris que sur les sols noirs, tandis que les engrais azotés révélaient des augmentations bien nettes sur les sols gris, et le phosphore une augmentation bien tranchée sur les sols noirs. Cet engrais n'a pas non plus exercé une action "après coup" sur les récoltes de grain. Le phoska-elsyn s'est montré inférieur dans ces essais à tous les autres engrais appliqués et comparés, et il n'y a pas eu d'augmentation significative dans une bonne proportion de ces essais. Les avantages que l'on attribue à cet engrais ne paraissent donc reposer sur aucun fondement.

DIGESTIBILITY STUDIES WITH RUMINANTS.

II. PLANE OF NUTRITION AND DIGESTIBILITY OF A HAY-BARLEY RATION

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In a previous paper (14) it was shown that the plane of nutrition did not affect the digestibility of a ration of mixed clover and grass hay fed to steers. The study is continued here with a ration of equal parts by weight of hay and barley. This is a production ration in its simplest form. As such it differs from the one in the previous publication in two respects. In the first place it can be fed at higher levels in respect to maintenance and in the second place it contains a larger percentage of "soluble" carbohydrates.

LITERATURE

Data concerning the effect of the plane of nutrition on the digestibility of production rations by ruminants may be found in the publications of Armsby and Fries (1), Armsby, Fries and Braman (2), Eckles (3), Forbes and his associates (5, 6), Honcamp and Koch (8), Jordan and Jentner (10), Mitchell and Hamilton (11), Mumford, Grindley, Hall and Emmett (12), and Poijärvi (13).

The data in these papers do not always lead to the same conclusions. As the plane of nutrition increased, there was, in some cases, a marked and progressive drop in the digestibility. In others a slight but distinct drop occurred at the higher levels, while in one case, an initial increase was followed by a decrease. Sometimes the results applied to all the nutrients of the feed. On other occasions they applied only to the dry matter, organic matter and nitrogen-free extract.

It may be generally concluded, therefore, that in the case of a production ration, at the higher levels of feeding, the digestibility of some, at least, of the nutrients is lowered. The questions remain however, as to how large or how small this reduction may be, at what level it develops and what nutrients are most affected.

EXPERIMENTAL

Using four grade Shorthorn steers as experimental animals, digestion trials were conducted on a ration consisting of equal parts by weight of hay and ground barley. The steers were approximately two and one-half years old and averaged 546 kilogrammes in live weight. The ration was fed at five levels, namely, 1.0, 2.0, 3.25, 4.5 and 5.0 kilogrammes of each

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feeding stuff per animal per day. These levels will hereinafter be denoted by the roman numerals, I, II, III, IV and V. As in the previous paper, the levels of II to V, inclusive, were set out in the form of a 4 × 4 square, the lowest level, I, being undertaken at the conclusion of the other trials.

The highest level originally chosen was 5.75 kilogrammes of each feeding stuff. It was found, however, in the first period that the animal on this level was refusing somewhat over 1 kilogramme of the mixture per day. Because of the uncertainty attached to such a large refusal, particularly in the case of mixed rations, it was necessary to lower the top level to 5.0 kilogrammes of each feeding stuff per animal per day. It was further necessary to repeat this first period in order to maintain the balance of the 4 × 4 square. All of the results are, however, presented in the paper.

The schedule of the digestion trials is given in Table 1. The experimental data are presented in Tables 8 and 9 in the appendix.

TABLE 1.—SCHEDULE OF DIGESTION TRIALS*

Period No.	Dates of Collection periods	Animal A	Animal B	Animal C	Animal D
	1935				
1	Jan. 28 to Feb. 9	II	III	IV	V
2	Feb. 25 to Mar. 9	IV	II	V	III
3	Mar. 25 to Apr. 6	V	IV	III	II
4	Apr. 22 to May 4	III	V	II	IV
5	May 20 to June 1	II	III	IV	V
6	June 17 to June 29	I	I	I	I

* The animals are denoted by capital letters, the plane of nutrition by roman numerals and the period by arabic numerals. Periods 2 to 5 inclusive form the 4 × 4 square.

DISCUSSION OF RESULTS

The average coefficients of digestibility for the individual nutrients are given in Table 2.

TABLE 2.—AVERAGE COEFFICIENTS OF DIGESTIBILITY*

	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Mean	71.2	72.6	66.8	68.3	43.6	82.6
Coefficient of variation†	2.13	2.12	4.92	4.26	9.51	1.20
Standard error†	±0.31	±0.31	±0.67	±0.59	±0.85	±0.20

* 24 individual values were averaged. Coefficients expressed in per cent.

† In the statistical treatment of the data, Fisher's methods (4) have been used; i.e. Standard Error = $\frac{\sigma}{\sqrt{n}}$

From the data in Table 2 it is evident that the 24 individual values for the coefficients of digestibility of the dry matter, organic matter and nitrogen-free extract were closely grouped for each nutrient. On the other hand, the values for the digestibility of the crude fibre showed rather large

variations, the coefficient of variation being 9.51 and the standard error, ±0.85. The variations in the values for the nitrogen and ether extract were intermediate.

TABLE 3.—COEFFICIENTS OF DIGESTIBILITY ARRANGED BY PLANES OF NUTRITION*

Plane	I	II	III	IV	V
Dry Matter	70.8	72.2	74.2	72.2	71.6
	69.2	73.0	72.7	71.3	70.0
	71.6	72.2	73.0	70.6	70.1
	72.3	71.9	70.0	71.0	70.1
		68.4	70.5	69.1	69.3
Mean	71.0	71.7	72.1	70.8	70.2
Coefficient of Variation	1.88	2.81	2.46	1.61	1.20
Standard Error..............	±0.67	±0.90	±0.79	±0.51	±0.38
Organic Matter	72.8	73.6	75.6	73.8	73.2
	70.9	75.1	74.1	72.4	71.3
	73.1	73.6	74.4	72.0	71.4
	74.2	73.5	71.5	72.7	71.4
		69.7	72.0	70.6	70.5
Mean	72.8	73.1	73.5	72.3	71.6
Coefficient of Variation	1.89	2.75	2.34	1.61	1.39
Standard Error	±0.69	±0.90	±0.77	±0.52	±0.44
Nitrogen	66.7	70.2	72.7	67.4	67.2
	68.8	70.9	67.3	64.9	61.7
	70.5	71.6	68.3	64.7	64.5
	70.1	67.9	65.4	63.8	60.6
		66.7	66.8	61.3	63.6
Mean	69.0	69.5	68.1	64.4	63.5
Coefficient of Variation	2.48	2.99	4.08	3.41	4.04
Standard Error	±0.86	±0.93	±1.24	±0.98	±1.15
Ether Extract	71.7	64.1	66.0	67.2	63.0
	67.0	71.5	66.0	71.6	63.2
	69.8	65.6	67.4	65.6	65.6
	70.3	71.9	69.1	69.7	69.7
		72.0	69.4	71.5	70.5
Mean	69.7	69.0	67.6	69.1	66.4
Coefficient of Variation	2.83	5.58	2.41	3.84	5.33
Standard Error	±0.99	±1.72	±0.73	±1.19	±1.58
Crude Fibre	42.8	45.7	51.2	48.5	47.4
	37.5	47.7	47.5	42.7	40.4
	41.4	42.0	49.4	44.3	43.9
	45.1	43.8	40.9	44.8	43.5
		31.7	43.2	41.0	40.0
Mean	41.7	42.2	46.4	44.3	43.0
Coefficient of Variation	7.65	14.77	9.25	6.32	6.99
Standard Error	±1.59	±2.79	±1.92	±1.25	±1.34

TABLE 3.—COEFFICIENTS OF DIGESTIBILITY ARRANGED BY PLANES OF NUTRITION*—*Conc.*

Plane	I	II	III	IV	V
N-free Extract	83.2 81.9 83.4 84.0	83.1 84.1 83.8 83.5 81.8	84.0 83.6 83.3 81.9 81.9	82.9 82.2 82.0 82.6 81.0	82.6 82.6 81.0 81.6 81.0
Mean	83.1	83.3	82.9	82.1	81.8
Coefficient of Variation	1.06	1.08	1.18	0.89	0.99
Standard Error	±0.44	±0.40	±0.44	±0.33	±0.36

* Coefficients in per cent.

TABLE 4.—STATISTICAL ANALYSES OF THE DATA IN TABLE 3*

	Variance due to	Variance	$\frac{1}{2}$ loge V	Z
Dry Matter	Plane of Nutrition Error	2.82 2.20	0.5175 0.3938	0.1237
Organic Matter	Plane of Nutrition Error	2.73 2.29	0.5017 0.4147	0.0870
Nitrogen	Plane of Nutrition Error	36.88 5.30	1.8038 0.8341	0.9697
Ether Extract	Plane of Nutrition Error	8.50 8.43	1.0699 1.0665	0.0034
Crude Fibre	Plane of Nutrition Error	16.92 17.26	1.4143 1.4243†	
N-free Extract	Plane of Nutrition Error	2.09 0.75	0.3680 1.8548	0.5132

* Degrees of freedom from "plane" = 4; degrees of freedom for "error" = 19. z for P .05 = 0.5315; z for P .01 = 0.7521.

† Variance due to plane less than variance due to error.

In Table 3 all the coefficients of digestibility have been arranged by plane of nutrition. In Table 4 the variance due to plane has been compared with that due to error.

From the data in these tables it will be noted that a marked drop in digestibility, progressive from the second level, occurred in the case of the nitrogen. This drop was, statistically, highly significant. In regard to the dry matter, organic matter, ether extract and nitrogen-free extract, the coefficients of digestibility showed a slight decrease at the highest level, but the differences were within the limits of experimental error. No significant change took place in the digestibility of the crude fibre.

In Table 5 the coefficients of digestibility for periods 2 to 5 inclusive, representing the 4 × 4 square, have been arranged by periods and by animals. In Table 6 the average coefficients of digestibility for the various nutrients at each level have been presented, while in Table 7 the analysis of variance has been summarized.

TABLE 5.—COEFFICIENTS OF DIGESTIBILITY OF LEVELS II TO V ARRANGED IN 4 × 4 SQUARE

	Period No.	Animal A	Animal B	Animal C	Animal D	Means
Dry Matter	2	(IV) 71.3	(II) 73.9	(V) 70.0	(III) 72.7	72.0
	3	(V) 70.1	(IV) 70.6	(III) 73.0	(II) 72.2	71.5
	4	(III) 70.0	(V) 70.1	(II) 71.9	(IV) 71.0	70.8
	5	(II) 68.4	(III) 70.5	(IV) 69.1	(V) 69.3	69.3
	Means	70.0	71.3	71.0	71.3	70.9
Organic Matter	2	(IV) 72.4	(II) 75.1	(V) 71.3	(III) 74.1	73.2
	3	(V) 71.4	(IV) 72.0	(III) 74.4	(II) 73.6	72.9
	4	(III) 71.5	(V) 71.4	(II) 73.5	(IV) 72.7	72.3
	5	(II) 69.7	(III) 72.0	(IV) 70.6	(V) 70.5	70.7
	Means	71.3	72.6	72.5	72.7	72.3
Nitrogen	2	(IV) 64.9	(II) 70.9	(V) 61.7	(III) 67.3	66.2
	3	(V) 64.5	(IV) 64.7	(III) 68.3	(II) 71.6	67.3
	4	(III) 65.4	(V) 60.6	(II) 67.9	(IV) 63.8	64.4
	5	(II) 66.7	(III) 66.8	(IV) 61.3	(V) 63.6	64.6
	Means	65.4	65.8	64.8	66.6	65.6
Ether Extract	2	(IV) 71.6	(II) 71.5	(V) 63.2	(III) 66.0	68.1
	3	(V) 65.6	(IV) 65.6	(III) 67.4	(II) 65.6	66.1
	4	(III) 69.1	(V) 69.7	(II) 71.9	(IV) 69.7	70.1
	5	(II) 72.0	(III) 69.4	(IV) 71.5	(V) 70.5	70.9
	Means	69.6	69.1	68.5	68.0	68.8
Crude Fibre	2	(IV) 42.7	(II) 47.7	(V) 40.4	(III) 47.5	44.6
	3	(V) 43.9	(IV) 44.3	(III) 49.4	(II) 42.0	44.9
	4	(III) 40.9	(V) 43.5	(II) 43.8	(IV) 44.8	43.3
	5	(II) 31.7	(III) 43.2	(IV) 41.0	(V) 40.0	39.0
	Means	39.8	44.7	43.7	43.6	42.9
N-free Extract	2	(IV) 82.2	(II) 84.1	(V) 82.6	(III) 83.6	83.1
	3	(V) 81.0	(IV) 82.0	(III) 83.3	(II) 83.8	82.5
	4	(III) 81.9	(V) 81.6	(II) 83.5	(IV) 82.6	82.4
	5	(II) 81.8	(III) 81.9	(IV) 81.0	(V) 81.0	81.4
	Means	81.7	82.4	82.6	82.8	82.4

* Coefficients in per cent. Treatments shown by Roman Numerals.

TABLE 6.—AVERAGE COEFFICIENTS OF DIGESTIBILITY AT EACH PLANE IN PERIODS 2, 3, 4 AND 5

Plane	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
II	71.6	73.0	69.3	70.3	41.3	83.3
III	71.6	73.0	67.0	68.0	45.3	82.7
IV	70.5	71.9	63.7	69.6	43.2	82.0
V	69.9	71.2	62.6	67.3	42.0	81.6

(* Coefficients in per cent.)

TABLE 7.—STATISTICAL ANALYSIS OF DATA IN TABLES 5 AND 6*

	Variance due to	Degrees of freedom	Sums of squares of deviations	Variance	$\frac{1}{2}$ loge V	z between plane and error
Dry Matter	Plane	3	8.56	2.85	0.5237	0.6109
	Animal	3	4.56	1.52	0.2094	
	Period	3	16.56	5.52	1.1272	
	Error	6	5.03	0.84	1.9128	
	Total	15	34.71	2.31		
Organic Matter	Plane	3	9.40	3.14	0.5721	0.6030
	Animal	3	5.16	1.72	0.2712	
	Period	3	14.92	4.97	0.8071	
	Error	6	5.64	0.94	1.9691	
	Total	15	35.12	2.34		
Nitrogen	Plane	3	113.04	37.68	1.8146	1.6645
	Animal	3	6.88	2.29	0.4143	
	Period	3	22.76	7.59	1.0134	
	Error	6	8.12	1.35	0.1501	
	Total	15	150.80	10.05		
Ether Extract	Plane	3	23.12	7.71	1.0213	0.1450
	Animal	3	5.84	1.95	0.3365	
	Period	3	55.52	18.51	1.4586	
	Error	6	34.63	5.77	0.8763	
	Total	15	119.11	7.94		
Crude Fibre	Plane	3	36.88	12.29	1.2544	0.0947
	Animal	3	55.92	18.64	1.4616	
	Period	3	89.04	29.68	1.6956	
	Error	6	61.00	10.17	1.1597	
	Total	15	242.84	16.19		
N-free Extract	Plane	3	6.80	2.27	0.4099	1.7395
	Animal	3	2.76	0.92	1.9583	
	Period	3	6.00	2.00	0.3466	
	Error	6	0.41	0.07	2.6704	
	Total	15	15.97	1.07		

* (z for P .05 = 0.7798; z for P .01 = 1.1401 for comparison of plane and error.)

From the results presented in these three tables, it will be observed that, as before, the effect of the plane of nutrition upon the coefficients of digestibility of the dry matter, organic matter, ether extract and crude fibre was not statistically significant, whereas the effect was statistically significant in the case of the nitrogen. In regard to the nitrogen-free extract, it will be noted that the variances due to plane, animal and period accounted for practically all of the total variance, leaving a negligible quantity ascribable to error. The effect of the plane of nutrition became, therefore, statistically significant in respect to the error. The decrease in digestibility, however, over the four levels was only 1.7 absolute per cent.

One outstanding observation to be made from Table 7 was the high variance due to the period and the low variance due to the animal. In the

case of the dry matter, organic matter, nitrogen and nitrogen-free extract, the variance due to period was significantly greater than that due to error. The variance due to animal was significantly higher than that due to error only in the case of the nitrogen-free extract, where, as mentioned above, the variance due to error was negligible. With the exception of the nitrogen and nitrogen-free extract, the variance due to plane was lower than that due to period, though not significantly so.

From the progressive nature of this decrease in digestibility through the four periods, it would seem as if either or both of two factors might be operating: First, the digestibilities of the feeds themselves may have undergone some slight change during the year; or, second, the digestive powers of the animals may have been somewhat affected by the long-continued monotony of the diet.

Apparently the only information relating to this point is to be found in a publication by Honcamp, Müllner and Stau (7). With sheep as experimental animals, these authors found that over a period of two to three years, no appreciable change took place in the digestibility of either a clover hay or a meadow hay.

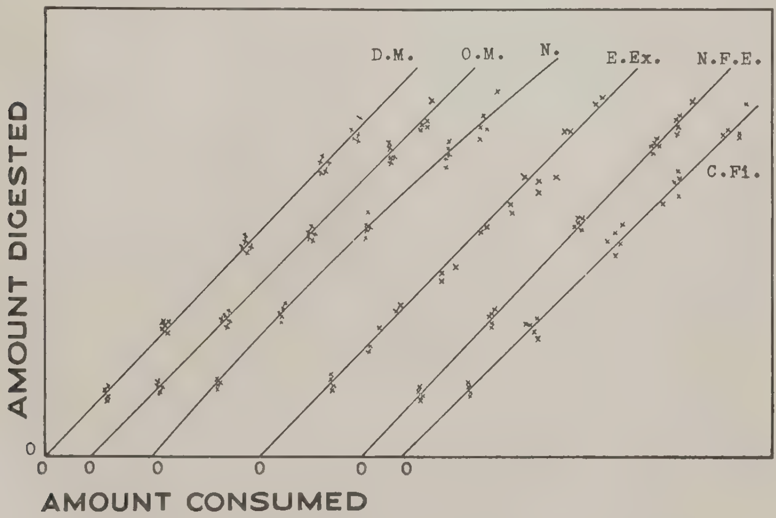

FIGURE 1. Quantity digested plotted on ordinate against quantity consumed plotted on abscissa for each nutrient. Graphs fitted to data to pass through the origin. Six different origins shown to facilitate spacing. Legend—O = origin, D.M. = dry matter, O.M. = organic matter, N = nitrogen, E.Ex = ether extract, C.Fi = crude fibre, N.F.E. = nitrogen-free extract.

The data given in tabular form in the above discussion have been presented graphically in Figure 1. The quantities of each nutrient consumed have been plotted on the abscissa and the quantities of each nutrient digested on the ordinate. Straight lines, passing through the origin, have been fitted to the data for the dry matter, organic matter, ether extract, crude fibre and nitrogen-free extract. A curve of the second degree,

passing through the origin, has been fitted to the nitrogen data. The curved nature of the nitrogen line, although not very marked in the figure, is indicative of a decrease in digestibility as the plane of nutrition is increased. The straight lines in the cases of the other nutrients demonstrate the constancy of the digestibility over the levels of feeding employed.

It would seem, therefore, in regard to this ration of hay and barley, as if the protein were the only constituent to be markedly affected by the plane of nutrition. For this nutrient the coefficients[5] of digestibility showed a decrease as the plane was increased. The nitrogen-free extract showed with increasing plane of nutrition a slight depression in digestibility which was statistically significant under certain conditions. Changes in the digestibility of the dry matter, organic matter, ether extract and crude fibre were not significant. The values for dry matter and organic matter, however, tended to be lower at the highest level of feeding. This lowering over the total range was, though, less than 2 absolute per cent and was within the experimental error.

SUMMARY AND CONCLUSIONS

A ration of equal parts by weight of hay and ground barley was fed to four steers at five levels of feeding, namely, 1.0, 2.0, 3.25, 4.5 and 5.0 kilogrammes of each feeding stuff per animal per day.

An analysis of the data yielded the following conclusions:

1. The "apparent" digestibility of the nitrogen decreased as the plane of nutrition was increased. The decrease over the whole range of feeding was approximately 6 absolute per cent. This difference was statistically highly significant.

2. The digestibility of the nitrogen-free extract showed a slight lowering as the plane of nutrition was increased. The decrease over the whole range of feeding was to the order of 1.5 absolute per cent. This became statistically significant when the variances due to the animal and period were eliminated. It was not significant when compared with the total variance due to period, animal and error.

3. The digestibilities of the dry matter, organic matter, ether extract and crude fibre were not significantly affected by the plane of nutrition.

4. The variance due to the individuality of the animals was comparatively small.

5. The variance due to the period was comparatively large.

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Professor E. W. Crampton, Macdonald College, very kindly examined the statistical treatment and interpretation of results in the above paper and offered certain valuable suggestions thereto.

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[5] Meaning the "apparent" coefficient of digestibility.

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Résumé

Étude de digestibilité sur les ruminants—II. Niveau de nutrition et digestibilité d'une ration de foin-orge. C. J. Watson, J. C. Woodward, W. M. Davidson, G. W. Muir et C. H. Robinson, Ferme expérimentale centrale, Ottawa, Ontario.

Une ration composée de parties égales par poids de foin et d'orge moulue a été donnée à quatre bœufs en cinq quantités différentes, savoir: 1.0, 2.0, 3.25, 4.5, et 5.0 kilogrammes de chaque aliment, par animal et par jour. Une analyse des données porte aux conclusions suivantes: La digestibilité "apparente" de l'azote diminue à mesure que le "niveau de nutrition" monte. La diminution sur toute la série d'essais d'alimentation a été d'environ 6 pour cent absolu. Au point de vue statistique, cette différence avait une haute importance. La digestibilité de l'extrait sans azote allait légèrement en diminuant à mesure que le niveau de la nutrition était haussé. La diminution sur toute la série d'essais était dans l'ordre de 1.5 pour cent absolu. Ce résultat avait une importance statistique lorsqu'on éliminait les variations dues à l'animal et à la période. Il n'avait aucune signification lorsqu'il était comparé à la variation totale, due à la période, à l'animal et à l'erreur. La digestibilité de la matière sèche, de la matière organique, de l'extrait d'éther et de la fibre brute n'était pas affectée d'une façon significative par le niveau de nutrition. La variation due à l'individualité des animaux était relativement faible. La variation due à la période était relativement forte.

APPENDIX

Table 8.—Composition of feeding stuffs in per cent

	Period 1		Period 2		Period 3		Period 4		Period 5		Period 6	
	Hay	Barley	Hay	Barley	Hay	Barley	Hay	Barley	Hay	Barley	Hay	Barley
Moisture	6.84	11.28	7.22	10.40	7.49	10.01	7.24	9.60	7.37	9.66	7.84	9.32
Ash	7.15	2.26	7.36	2.24	7.34	2.23	7.45	2.19	7.08	2.19	7.23	2.21
Crude protein*	11.42	12.04	11.81	11.63	11.32	12.01	11.34	11.89	11.07	12.10	11.53	12.15
Ether extract	2.43	0.91	2.67	1.28	2.70	1.02	2.78	1.79	2.49	2.02	2.71	2.03
Crude fibre	28.72	6.45	27.45	6.49	28.30	6.61	28.21	6.56	28.68	6.68	27.81	6.89
N-free extract	43.44	67.06	43.49	67.96	42.85	68.12	42.98	67.97	43.31	67.35	42.88	67.40

* Protein factors (9)—6.25 for hay and 5.83 for barley.

TABLE 9.—DATA FOR CALCULATION OF COEFFICIENTS OF DIGESTIBILITY
(Collection period of 12 days)

	Animal No.	Original weights of feeds or feces	Nutrients					
			Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free Extract
Period 1								
In hay (kilos)	A	24	22.358	20.642	0.439	0.583	6.893	10.426
	B	39	36.332	33.544	0.713	0.948	11.201	16.942
	C	54	50.306	46.445	0.987	1.312	15.509	23.458
	D	69	64.280	59.347	1.261	1.677	19.817	29.974
In barley (kilos)	A	24	21.343	20.813	0.497	0.302	1.548	16.068
	B	39	34.683	33.821	0.807	0.491	2.516	26.111
	C	54	48.022	46.829	1.117	0.680	3.483	36.153
	D	69	61.362	59.837	1.428	0.869	4.451	46.196
Refused (kilos)	D	13.991	13.089	12.402	0.267	0.298	2.871	7.562
In feces (kilos)	A	69.180	12.164	10.932	0.279	0.318	4.581	4.472
	B	96.998	18.328	16.430	0.415	0.489	6.696	6.900
	C	181.536	27.305	24.392	0.685	0.653	9.779	10.205
	D	205.820	31.966	28.594	0.795	0.832	11.262	11.967
Coefficients (%)	A		72.2	73.6	70.2	64.1	45.7	83.1
	B		74.2	75.6	72.7	66.0	51.2	84.0
	C		72.2	73.8	67.2	67.2	48.5	82.9
	D		71.6	73.2	67.2	63.0	47.4	82.6
Period 2								
In hay (kilos)	A	54	50.101	46.127	1.020	1.442	14.823	23.485
	B	24	22.267	20.501	0.453	0.641	6.588	10.438
	C	60	55.668	51.252	1.133	1.602	16.470	26.094
	D	39	36.184	33.314	0.737	1.041	10.706	16.961
In barley (kilos)	A	54	48.384	47.174	1.077	0.691	3.505	36.698
	B	24	21.504	20.966	0.479	0.307	1.558	16.310
	C	60	53.760	52.416	1.197	0.768	3.894	40.776
	D	39	34.944	34.070	0.778	0.499	2.531	26.504
In feces (kilos)	A	184.144	28.311	25.790	0.735	0.606	10.495	10.689
	B	68.740	11.415	10.311	0.271	0.270	4.258	4.245
	C	233.160	32.859	29.762	0.892	0.872	12.139	11.604
	D	121.577	19.416	17.419	0.496	0.523	6.946	7.132
Coefficients (%)	A		71.3	72.4	64.9	71.6	42.7	82.2
	B		73.9	75.1	70.9	71.5	47.7	84.1
	C		70.0	71.3	61.7	63.2	40.4	82.6
	D		72.7	74.1	67.3	66.0	47.5	83.6
Period 3								
In hay (kilos)	A	60	55.506	51.102	1.087	1.620	16.980	25.710
	B	54	49.955	45.992	0.978	1.458	15.282	23.139
	C	39	36.079	33.216	0.706	1.053	11.037	16.712
	D	24	22.202	20.441	0.435	0.648	6.792	10.284
In barley (kilos)	A	60	53.994	52.656	1.237	0.612	3.966	40.872
	B	54	48.595	47.390	1.113	0.551	3.569	36.785
	C	39	35.096	34.226	0.804	0.398	2.578	26.567
	D	24	21.598	21.062	0.495	0.245	1.586	16.349
In feces (kilos)	A	214.755	32.743	29.679	0.826	0.768	11.744	12.621
	B	187.021	28.934	26.174	0.738	0.691	10.498	10.792
	C	123.285	19.238	17.240	0.479	0.473	6.890	7.242
	D	64.042	12.167	10.944	0.264	0.307	4.862	4.307

TABLE 9.—DATA FOR CALCULATION OF COEFFICIENTS OF DIGESTIBILITY—*Concluded*
(Collection period of 12 days)—*Concluded*

	Animal No.	Original weights of feeds or feces	Nutrients: Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free Extract
Period 3—Con.								
Coefficients (%)	A		70.1	71.4	64.5	65.6	43.9	81.0
	B		70.6	72.0	64.7	65.6	44.3	82.0
	C		73.0	74.4	68.3	67.4	49.4	83.3
	D		72.2	73.6	71.6	65.6	42.0	83.8
Period 4								
In hay (kilos)	A	39	36.176	33.271	0.707	1.084	11.002	16.762
	B	60	55.656	51.186	1.088	1.668	16.926	25.788
	C	24	22.262	20.474	0.435	0.667	6.770	10.315
	D	54	50.090	46.067	0.980	1.501	15.233	23.209
In barley (kilos)	A	39	35.256	34.402	0.795	0.698	2.558	26.508
	B	60	54.240	52.926	1.223	1.074	3.936	40.782
	C	24	21.696	21.170	0.489	1.430	1.574	16.313
	D	54	48.816	47.633	1.101	0.967	3.542	36.704
In feces (kilos)	A	134.334	21.406	19.294	0.520	0.551	8.015	7.839
	B	208.851	32.808	29.764	0.911	0.830	11.793	12.280
	C	76.495	12.368	11.029	0.297	0.308	4.691	4.392
	D	193.209	28.713	25.618	0.754	0.747	10.357	10.444
Coefficients (%)	A		70.0	71.5	65.4	69.1	40.9	81.9
	B		70.1	71.4	60.6	69.7	43.5	81.6
	C		71.9	73.5	67.9	71.9	43.8	83.5
	D		71.0	72.7	63.8	69.7	44.8	82.6
Period 5								
In hay (kilos)	A	24	22.231	20.532	0.425	0.598	6.883	10.394
	B	39	36.126	33.365	0.690	0.971	11.185	16.891
	C	54	50.020	46.197	0.956	1.345	15.487	23.387
	D	60	55.578	51.330	1.062	1.494	17.208	25.986
In barley (kilos)	A	24	21.682	21.156	0.498	0.485	1.603	16.164
	B	39	35.233	34.379	0.809	0.788	2.605	26.267
	C	54	48.784	47.601	1.121	1.091	3.607	36.369
	D	60	54.204	52.890	1.245	1.212	4.008	40.410
In feces (kilos)	A	79.265	13.892	12.648	0.307	0.303	5.794	4.845
	B	119.755	21.020	18.970	0.498	0.538	7.834	7.791
	C	208.021	30.497	27.582	0.803	0.695	11.260	11.329
	D	219.993	33.756	30.716	0.840	0.799	12.738	12.647
Coefficients (%)	A		68.4	69.7	66.7	72.0	31.7	81.8
	B		70.5	72.0	66.8	69.4	43.2	81.9
	C		69.1	70.6	61.3	71.5	41.0	81.0
	D		69.3	70.5	63.6	70.5	40.0	81.0
Period 6								
In hay	All animals	24	11.059	10.192	0.221	0.325	3.337	5.146
In barley	All animals	24	10.882	10.616	0.250	0.244	0.827	8.088
In feces (kilos)	A	32.957	6.416	5.663	0.157	0.161	2.380	2.222
	B	24.884	6.758	6.051	0.147	0.188	2.602	2.389
	C	26.698	6.242	5.605	9.139	0.172	2.439	2.194
	D	29.469	6.069	5.376	0.141	0.169	2.284	2.119
Coefficients (%)	A		70.8	72.8	66.7	71.7	42.8	83.2
	B		69.2	70.9	68.8	67.0	37.5	81.9
	C		71.6	73.1	70.5	69.8	41.4	83.4
	D		72.3	74.2	70.1	70.3	45.1	84.0

THE DIGESTIBILITY OF CANADIAN FEEDING STUFFS—SOYBEAN OIL MEAL

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Continuing the studies on the digestibility of Canadian feeding stuffs, data are presented in this paper for soybean oil meal, produced by the expeller process. A comparison is also made between the feeding values of this soybean oil meal and of linseed oil meal upon the basis of digestibility trials.

LITERATURE

With sheep as experimental animals, the coefficients of digestibility of soybean oil meal have been determined in the United States by Hamilton, Mitchell and Kammlade (2), in Germany by Malkomesius and Schramm (5) and also by Honcamp, Helms, Malkomesius, Meier and Naumann (3). With cattle as experimental animals, the coefficients have been determined in Denmark by Andersen and Frederiksen (1).

In general, these investigations indicated a high digestibility of all the nutrients in soybean oil meal. In the case of crude fibre, however, satisfactory coefficients were not, as a rule, obtained. Not only were the individual variations very large but the calculated values were in some cases negative and in other cases more than 100%. This was probably due in part to the small amount of crude fibre in the soybean oil meal as compared with the basal ration and in part to an "associative" effect.

EXPERIMENTAL

Two experiments were conducted, one in 1933 and the other in 1934. In the 1933 experiment, the coefficients of digestibility of soybean oil meal were determined with four grade Shorthorn steers numbered, in this report 1, 2, 3 and 4. They were between two and one-half and three years old and averaged 519 kilogrammes in live weight. A mixed clover and grass hay was used as the basal ration. Five kilogrammes were fed with three kilogrammes of soybean oil meal per animal per day.

In 1934 the experiment was repeated. At the same time the coefficients of digestibility of linseed oil meal were also determined in order to make a direct comparison between the two feeds. Four grade Shorthorn steers were again used, numbered 5, 6, 7 and 8. Their age was two and one-half years and their average live weight was 523 kilogrammes. The set up of the 1934 experiment is given in Table 1.

The hay alone was fed at a rate of 7.5 kilogrammes per animal per day. In the mixed rations, the hay was fed at a rate of 5.0 kilogrammes per day and the concentrates at a rate of 3.0 kilogrammes per day.

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TABLE 1.—SCHEDULE OF THE 1934 EXPERIMENT

Period	Composition of ration			
	Animal 5	Animal 6	Animal 7	Animal 8
1	Hay	Hay and soybean oil meal	Hay and linseed oil meal	Hay
2	Hay and soybean oil meal	Hay and linseed oil meal	Hay	Hay and linseed oil meal
3	Hay and linseed oil meal	Hay	Hay and soybean oil meal	Hay and soybean oil meal

In both experiments a preliminary period of twelve to fourteen days was followed by a collection period of twelve days.

PRESENTATION OF RESULTS

The experimental data are presented in Tables 5 to 9 in the appendix.

A summary of the coefficients of digestibility of soybean oil meal and linseed oil meal is given in Table 2.

TABLE 2.—COEFFICIENTS OF DIGESTIBILITY IN PER CENT OF SOYBEAN OIL MEAL AND OF LINSEED OIL MEAL

Animal No.	Coefficients of digestibility						
	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Total* carbohydrates
Soybean Oil Meal—1933 Results							
1	88.6	90.4	90.0	89.5	119	86.5	91.6
2	90.6	92.8	91.3	88.7	115	92.1	95.8
3	86.3	87.7	87.2	87.3	119	82.6	88.4
4	87.5	89.0	88.9	87.5	116	85.5	90.4
Mean	88.3	90.0	89.4	88.3	117	86.7	91.6
Coeff. of Variation	2.07	2.42	1.94	1.18	1.78	4.59	3.41
Standard Error	±0.92	±1.09	±0.87	±0.52	±1·0	±1.99	±1.56
Soybean Oil Meal—1934 Results							
5	85.5	88.0	87.2	87.4	116	80.1	87.3
6	82.3	85.1	87.7	79.6	84	81.6	82.2
7	85.4	88.8	87.0	92.9	117	80.0	87.5
8	85.3	88.4	87.4	91.2	105	82.0	86.6
Mean	84.6	87.6	87.3	87.8	106	80.9	85.9
Coeff. of Variation	1.83	1.92	0.34	6.74	14.5	1.27	2.91
Standard Error	±0.78	±0.84	±0.15	±2.96	±7.67	±0.51	±1.25

TABLE 2.—COEFFICIENTS OF DIGESTIBILITY IN PER CENT OF SOYBEAN OIL MEAL AND OF LINSEED OIL MEAL—*Concluded*

Animal No.	Coefficients of digestibility						
	Dry matter	Organic matter	Nit-rogen	Ether extract	Crude fibre	N-free extract	Total* carbo-hydrates
Soybean Oil Meal—Results for both years							
Mean	86.8	88.8	88.3	88.0	111	83.8	88.7
Coeff. of Variation	2.89	2.49	1.79	4.48	10.7	4.87	4.51
Standard Error	±0.88	±0.78	±0.56	±1.39	±4.2	±1.44	±1.41
Linseed Oil Meal—1934 Results							
5	74.7	76.4	83.7	96.7	53.5	70.5	66.6
6	77.5	79.1	85.0	95.5	74.4	70.1	71.1
7	70.4	72.4	82.8	89.9	30.3	71.0	61.4
8	75.6	77.3	84.5	95.2	64.7	69.7	68.5
Mean	74.6	76.3	84.0	94.3	55.7	70.3	66.9
Coeff. of Variation	4.02	3.71	1.15	3.20	34.1	0.79	6.13
Standard Error	±1.50	±1.42	±0.48	±1.51	±9.5	±0.28	±2.05

* Since the calculated values of crude fibre in soy bean oil meal were more than 100%, this nutrient has been combined with the N-free extract to give the "total carbohydrates".

In Table 3, soybean oil meal and linseed oil meal have been compared on the basis of their contents in crude and digestible nutrients. The 1934 results only were used.

TABLE 3.—CONTENTS OF SOYBEAN OIL MEAL AND LINSEED OIL MEAL IN CRUDE AND DIGESTIBLE NUTRIENTS. 1934 RESULTS

Crude nutrients in per cent of dry matter			Digestible nutrients in pounds per 100 pounds of dry matter		
	Soybean oil meal	Linseed oil meal		Soybean oil meal	Linseed oil meal
Ash	7.77	5.09	Protein*	35.98	29.88
Protein*	41.21	35.57	Ether extract	6.01	7.86
Ether extract	6.84	8.33	Total carbohydrates	37.95	34.13
Crude fibre	9.07	11.91	Total digestible	87.45	81.70
N-free extract	35.11	39.10			

* Protein = N × 6.25 Jones (4) has rightly pointed out the erroneous nature of this factor for the oil seeds. It has been retained throughout this paper to conform with the commercial feed standards.

In Table 4 the results obtained on soybean oil meal in this investigation have been compared with those obtained in other countries.

TABLE 4.—COMPOSITION AND DIGESTIBILITY OF SOYBEAN OIL MEAL FROM DIFFERENT SOURCES

Country	Canada		Denmark*	Germany				United States	
Authority	This investigation		Andersen and Frederiksen (1)	Malkomesius and Schramm (5)		Honcamp et al (3)		Hamilton, Mitchell and Kammlade (2)	
Species of Animal	Cattle		Cattle	Sheep		Sheep		Sheep	
No. of trials	8		Not given	5		6		24	
Chemical Composition on Dry Matter Basis									
	%		%	%		%		%	
Ash	7.54		6.2	6.66		6.00		7.24	
Protein	41.96		50.6	53.57		51.99		43.6	
Ether extract	6.85		7.9	1.15		0.77		5.88	
Crude fibre	8.00		5.0	4.84		5.13		8.45	
N-free extract	35.65		30.3	33.78		36.11		34.8	
Coefficients of Digestibility with Standard Errors									
	%	S.E.	%	%	S.E.	%	S.E.	%	S.E.
Dry matter	86.4	±0.88	†	88.6	±1.95	†		86.8	± 6.22
Organic matter	88.8	±0.78	90	91.4	±1.97	95.6	±0.64	†	
Nitrogen	88.3	±0.56	88	95.1	±0.45	93.0	±0.26	83.9	± 2.65
Ether extract	88.0	±1.39	90	70.3	±7.37	47.0	±3.85	87.3	± 5.63
Crude fibre	‡		82	64.2	±17.8	‡		‡	
N-free extract	83.8	±1.44	96	91.0	±2.54	97.0	±0.65	98.1	± 4.63
Carbohydrates	88.7	±1.41	94	87.1	±4.17	100.4	±1.33	99.8	±11.6
Digestible Nutrients per 100 Pounds Dry Matter									
	lbs.		lbs.	lbs.		lbs.		lbs.	
Protein	37.05		44.53	50.95		48.35		36.6	
Ether extract	6.03		7.11	0.81		0.36		5.13	
Carbohydrates	38.72		33.18	33.64		41.40		43.2	
Total	89.34		92.71	86.41		90.56		91.3	

* Pressed soybean cake imported from Manchuria.
† Data not given.
‡ Calculated values were more than 100 per cent.

DISCUSSION OF RESULTS

From the data contained in Table 2, it is evident that the soybean oil meal in this experiment was a highly digestible feeding stuff. The coefficients of digestibility determined in 1933 were slightly higher than those determined in 1934, particularly in regard to the carbohydrates.

The comparative feeding values of soybean oil meal and linseed oil meal as used in this investigation may be estimated from the data in Tables 2 and 3 obtained in 1934. With the exception of the ether extract, the digestibilities of the nutrients in the linseed meal were lower than those in the soybean meal. The difference in the case of the protein was, however, slight.

In regard to the chemical composition, the linseed oil meal was lower in crude and digestible protein and in total digestible nutrients.[5]

On the basis of the data in Table 3, money values were assigned to the two feeding stuffs using the method of Petersen (6) as applied to Canadian conditions by Stothart (7). In employing this method, the assumption was made that in feeding practice units of protein and non-protein nutrients in linseed oil meal were equivalent, respectively, to similar units in soybean oil meal. With barley worth $24.73 per ton of dry matter and linseed oil meal $34.24, soybean oil meal would be worth $38.64 per ton of dry matter.

In Table 4, the results obtained in this investigation have been compared with those obtained in other countries. As far as the digestibility was concerned, the coefficients obtained on the Canadian meal closely approached those cited from other sources. The values obtained by Honcamp and his associates with sheep, however, were somewhat higher.

In regard to the chemical composition, the oil meals from the German sources being produced by the solvent process were characterized by the completeness with which the fat had been extracted. In addition, the protein contents were somewhat higher. The calculated values of the total digestible nutrients were of the same order for all the meals with the exception of those reported by Malkomesius and Schramm. These latter were lower, due to the low fat content. In the case of the data obtained by Honcamp, the low fat content was counterbalanced by a higher digestibility.

SUMMARY

With grade Shorthorn steers as experimental animals, digestibility trials were conducted on soybean oil meal and linseed oil meal.

Compared with linseed oil meal, the soybean oil meal contained more digestible protein and more total digestible nutrients per 100 pounds of dry matter.

On the basis of their contents of digestible nutrients, it was estimated that the soybean oil meal was worth from four to five dollars more per ton than linseed oil meal.

Data on the chemical composition and digestibility of the soybean oil meal obtained in this investigation were compared with similar data obtained in other countries. Differences were noted in the contents of crude protein and ether extract, but the coefficients of digestibility were of the same general order.

[5] On the Canadian market there are also soybean oil meals produced by the solvent process. Having a very low content of fat, these meals would have a lower content of total digestible nutrients, other things being equal.

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Résumé

Digestibilité des aliments canadiens—Tourteaux de soja. C. J. Watson, J. C. Woodward, W. M. Davidson, G. W. Muir et C. H. Robinson, Ferme expérimentale centrale, Ottawa, Ontario.

Des essais de digestibilité ont été conduits avec des tourteaux de soja et des tourteaux de lin; on s'est servi pour cette expérience de bœufs Shorthorn croisés. Les tourteaux de soja contenaient plus de protéine digestible que les tourteaux de lin et plus d'éléments digestibles totaux par 100 livres de matière sèche. Se basant sur leur teneur en éléments digestibles, on a constaté que les tourteaux de soja valaient de quatre à cinq dollars de plus la tonne que les tourteaux de lin. Les données recueillies sur la composition chimique et la digestibilité des tourteaux de soja ont été comparées avec des données semblables obtenues dans d'autres pays. Des différences ont été notées dans la teneur en protéine brute et en extrait d'éther, mais les coefficients de digestibilité étaient du même ordre général.

APPENDIX

Table 5.—Chemical compositions of feeding stuffs

	Moisture	Ash	Protein (Nx 6.25)	Ether extract	Crude fibre	N-free extract
Hay						
1933—Period 1	8.02	7.04	10.34	2.04	32.29	40.27
1933—Period 2	7.76	6.62	11.36	1.67	33.61	38.98
1934—Period 1	9.40	7.19	10.93	2.85	27.71	41.92
1934—Period 2	10.15	7.08	11.00	2.58	26.67	42.52
1934—Period 3	11.03	7.00	10.77	2.49	26.24	42.47
Soybean Meal						
1933	5.79	6.89	40.23	6.47	6.52	34.10
1934—Period 1	7.53	7.17	38.24	6.46	8.79	31.81
1934—Period 2	8.09	7.14	37.88	6.45	8.07	32.37
1934—Period 3	7.89	7.17	37.83	5.99	8.22	32.90
Linseed Meal						
1934—Period 1	6.06	4.71	33.56	8.08	11.26	36.33
1934—Period 2	6.90	4.71	33.18	7.54	11.20	36.47
1934—Period 3	6.69	4.85	32.98	7.74	10.93	36.81

TABLE 6.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF HAY IN 1933
(Collection period of 16 days)

	Original weight	Dry matter	Organic matter	Nit-rogen	Ether extract	Crude fibre	N-free extract
In hay (kilos)	116	106.70	98.530	1.919	2.366	37.457	46.713
In feces (kilos)							
Animal 1	275.225	46.05	40.977	0.873	1.224	18.619	16.061
Animal 2	341.960	47.36	42.117	0.854	1.284	19.542	16.423
Animal 3	277.124	47.61	42.452	0.884	1.241	19.681	16.501
Animal 4	311.640	47.01	42.081	0.844	1.274	19.719	16.216
Coefficient (%)							
Animal 1		56.8	58.4	54.5	48.3	50.3	65.6
Animal 2		55.6	57.3	55.5	45.7	47.9	64.9
Animal 3		55.4	56.9	53.9	47.5	47.5	64.7
Animal 4		55.9	57.3	56.0	46.1	47.4	65.3
Mean		55.9	57.5	55.0	46.9	48.3	65.1

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF SOYBEAN MEAL—1933
(Collection period of 12 days)

	Original weight	Dry matter	Organic matter	Nit-rogen	Ether extract	Crude fibre	N-free extract
In feeds (kilos)							
Hay	60	55.344	51.372	1.090	1.002	20.166	23.388
Soybean meal	36	33.916	31.435	2.317	2.329	2.347	12.276
Total	96	89.260	82.807	3.407	3.331	22.513	35.664
In feces (kilos)							
Animal 1	189.999	28.288	24.858	0.724	0.776	9.990	9.821
Animal 2	188.673	27.588	24.097	0.692	0.795	10.075	9.127
Animal 3	170 842	29.057	25.698	0.787	0.827	9.977	10.304
Animal 4	190.336	28.640	25.274	0.748	0.822	10.042	9.943
Digested from hay (kilos)		30.937	29.540	0.599	0.470	9.740	15.226
Digested from Soybean meal (kilos)							
Animal 1		30.035	28.409	2.084	2.085	2.783	10.617
Animal 2		30.735	29.170	2.116	2.066	2.698	11.311
Animal 3		29.269	27.569	2.021	2.034	2.796	10.134
Animal 4		29.683	27.993	2.060	2.039	2.731	10.495
Coefficients of soybean meal (%)							
Animal 1		88.6	90.4	90.0	89.5	119	86.5
Animal 2		90.6	92.8	91.3	88.7	115	92.1
Animal 3		86.3	87.7	87.2	87.3	119	82.6
Animal 4		87.5	89.0	88.9	87.5	116	85.5

TABLE 8.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF HAY—1934

(Collection period of 12 days)

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
In hay (kilos)							
Period 1	90	81.540	75.069	1.573	2.565	24.939	37.728
Period 2	90	80.865	74.493	1.584	2.322	24.003	38.268
Period 3	90	80.073	73.773	1.552	2.241	23.616	38.223
In feces (kilos)							
Animal 5*	193.33	32.055	28.649	0.660	1.126	14.748	9.037
Animal 6*	165.61	30.514	27.291	0.633	0.918	13.035	9.587
Animal 7*	177.39	30.935	27.220	0.661	0.930	13.843	8.787
Animal 8*	166.80	31.682	28.232	0.635	1.121	14.576	8.976
Coefficients (%)							
Animal 5		60.7	61.8	58.0	56.1	40.9	76.0
Animal 6		61.9	63.0	59.2	59.0	44.8	74.9
Animal 7		61.7	63.5	58.3	59.9	42.3	77.0
Animal 8;		61.1	62.4	59.6	56.3	41.6	76.2
Mean		61.4	62.7	58.8	57.8	42.4	76.0

* Animals 5 and 8 in Period 1, Animal 6 in Period 3, Animal 7 in Period 2.

TABLE 9.—CALCULATION OF COEFFICIEHTS OF DIGESTIBILITY OF SOYBEAN MEAL AND LINSEED MEAL—1934 RESULTS

(Collection period of 12 days)

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
In hay (kilos)							
Period 1	60	54.360	50.046	1.049	1.710	16.626	25.132
Period 2	60	53.910	49.662	1.056	1.548	16.002	25.512
Period 3	60	53.382	49.182	1.034	1.494	15.744	25.482
In soybean meal (kilos)							
Period 1	36	33.289	30.708	2.202	2.326	3.164	11.452
Period 2	36	33.088	30.517	2.182	2.322	2.905	11.653
Period 3	36	33.160	30.578	2.179	2.156	2.959	11.844
In linseed oil meal (kilos)							
Period 1	36	33.818	32.123	1.933	2.909	4.054	13.079
Period 2	36	33.516	31.820	1.911	2.714	4.032	13.129
Period 3	36	33.592	31.846	1.899	2.786	3.935	13.252
Digested from hay (kilos)							
Period 1		33.377	31.379	0.617	0.988	7.049	19.116
Period 2		33.101	31.138	0.621	0.895	6.785	19.389
Period 3		32.777	30.837	0.608	0.864	6.675	19.366

TABLE 9.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY OF SOYBEAN MEAL AND LINSEED MEAL. 1934 RESULTS—*Concluded*

(Collection period of 12 days)—*Concluded*

	Original weight	Dry matter	Organic matter	Nit-rogen	Ether extract	Crude fibre	N-free extract
In feces of soybean rations (kilos)							
Animal 5*	170.68	25.621	22.175	0.714	0.945	8.747	8.437
Animal 6*	161.71	26.873	23.256	0.703	1.196	10.073	8.139
Animal 7*	157.89	25.451	21.781	0.709	0.783	8.562	8.480
Animal 8*	147.04	25.485	21.903	0.700	0.819	8.920	8.252
Digested from soybean meal (kilos)							
Animal 5*		28.276	26.866	1.903	2.030	3.375	9.339
Animal 6*		27.399	26.119	1.931	1.852	2.668	9.349
Animal 7*		28.314	27.142	1.896	2.003	3.466	9.480
Animal 8*		28.280	27.020	1.905	1.967	3.108	9.708
Coefficients of soybean meal (%)							
Animal 5*		85.5	88.0	87.2	87.4	116	80.1
Animal 6*		82.3	85.1	87.7	79.6	84	81.6
Animal 7*		85.4	88.8	87.0	92.9	117	80.0
Animal 8*		85.3	88.4	87.4	91.2	105	82.0
In feces from linseed rations (kilos)							
Animal 5*	174.67	29.118	25.853	0.735	0.721	10.899	10.030
Animal 6*	161.32	28.337	25.162	0.721	0.776	10.249	10.050
Animal 7*	190.82	31.001	27.542	0.765	1.016	12.401	9.830
Animal 8*	161.38	28.992	25.743	0.731	0.782	10.641	10.107
Digested from linseed meal (kilos)							
Animal 5*		25.079	24.338	1.590	2.695	2.105	9.338
Animal 6*		25.988	25.182	1.625	2.591	3.000	9.202
Animal 7*		23.800	23.248	1.600	2.615	1.230	9.285
Animal 8*		25.333	24.601	1.615	2.585	2.608	9.145
Coefficients of linseed meal (%)							
Animal 5*		74.7	76.4	83.7	96.7	53.5	70.5
Animal 6*		77.5	79.1	85.0	95.5	74.4	70.1
Animal 7*		70.4	72.4	82.8	89.9	30.3	71.0
Animal 8*		75.6	77.3	84.5	95.2	64.7	69.7

* The soybean meal was fed in period 1 to animal 6, in period 2 to animal 5, in period 3 to animals 7 and 8. The linseed meal was fed in period 1 to animal 7, in period 2 to animals 6 and 8, in period 3 to animal 5.

SOME STUDIES ON THE CAUSES OF SOFT BACON

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The occurrence of a percentage of carcasses in regular killings in packing plants which are classified as "soft" is a matter of concern to those who are interested in the reputation of Canadian bacon. Such carcasses are objectionable to all phases of the bacon trade and for that reason it is important that the number be reduced to the lowest possible point. The soft pork problem was studied in Canada at an early stage in the development of an export market, and the experiments of Shutt (1) and Day (2, 3) stand out as classical contributions to the subject. The more recent comprehensive investigations in the United States (4) brought much light to bear on the causes of soft pork under conditions of American feeds and feeding practices and resulted in recommendations regarding methods of overcoming the difficulty. The early experiments referred to and the American investigations were, however, concerned to a considerable extent with feeds which are not at the present time regarded as staple feeds for bacon hogs.

During recent years in Western Canada, the problem of soft carcasses has become comparatively acute. At certain seasons of the year and from certain areas an alarmingly high percentage of the pigs yield carcasses which are graded as "soft" and which are not acceptable for export purposes.

Over a period of years this problem has been given recognition in the experimental work at the University of Alberta and it is the purpose of this paper to submit the results of certain trials which have been conducted.

In so far as the discussion which follows is concerned, it has been assumed that the problem of soft bacon is, strictly speaking, connected with soft fat. The fatty tissues have been regarded as those involved rather than the muscular tissues even though the percentage of moisture in the lean may vary, and the degree of finish or percentage of fat may also be a contributing factor in connection with the firmness or rigidity of a carcass. There would appear to be general agreement on the point that the objectionable feature of the soft carcass lies in the soft or oily nature of its fat, which in turn is due to the percentage of unsaturated fatty acids which it contains.

In connection with the experiments which were conducted, the degree of firmness of the fat in the majority of cases was determined on the basis of the iodine number. Samples of back fat were removed from individual carcasses above the junction of the sacrum and lumbar vertebrae and including a cross section of the fat layer. The back fat sample was taken since it was found in the American investigations (4) that fat from this region was more representative of the fat in carcass than that removed from other locations. Hand gradings were secured on the carcasses from certain experiments but the method was not adopted as a standard practice on account of the possibility of variation in the human factor and possible

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variations in temperatures at which physical gradings might be carried out. It is recognized that physical grading offers some advantage in assessing the practical "handling quality" of carcasses, but possesses limitations when the degree of softness of fat is under consideration. Since hand grading must be relied upon as a standard procedure in selecting or rejecting carcasses for export purposes, it is desirable that hand grading be correlated with such a chemical determination as the iodine number. In connection with the American soft pork investigations (4), physical grades were compared with such laboratory determinations as iodine number, refractive index and melting point. Hand grades in relation to the average iodine number were established as follows:— Hard—63, Medium hard—68, Medium soft—71, Soft—77.5. For the purpose of grading the fat samples obtained from the pigs removed from the experiments to be reported, those with iodine number below 63 were graded "hard", from 63 to 67 "medium hard", and those over 67 as "soft".

EXPERIMENTAL RESULTS

Proportion of Oats and Barley in the Ration

In view of the common usage of oats and barley in rations of bacon hogs, it was considered advisable during the years 1926, 1927 and 1928 to study the effect of varying the proportions of oats and barley in the ration on the firmness of fat in the carcass. In these experiments litter mate pigs were distributed in the various groups and were placed on trial immediately after weaning at eight weeks of age. During the first 28 days of the trial the pigs were confined to dry lot, and following this period they were placed on cereal mixture pasture. Hand-feeding four times daily was practised during the first 28 days and thereafter the feeding was done twice daily. Skim-milk was fed as a protein supplement at the rate of 3 lbs. to 1 lb. of grain until the pigs weighed 80 lbs., 2 lbs. to 1 lb. of grain from 80 lbs. to 125 lbs. and at the rate of 1.5 lbs. to 1 lb. of grain until the pigs reached a weight of approximately 200 lbs.

The oats fed in the trials had an average fat content of 5.12% with average iodine number of 75.6; the barley had an average fat content of 2.24% with iodine number of 97.7.

The results of these experiments are shown in Table. 1.

TABLE 1.—EFFECT OF PROPORTIONS OF OATS AND BARLEY ON FIRMNESS OF FAT

	Lot I Oats 2 Barley 1	Lot II Oats 1 Barley 1	Lot III Oats 1 Barley 2	Lot IV Oats 1 Barley 3	Lot V Barley alone
No. of pigs in group	20	20	20	20	19
Av. initial weight (lbs.)	35.7	36.1	36.1	36.2	35.8
Av. final weight (lbs.)	205.4	202.1	203.9	203.6	205.2
Av. daily gain (lbs.)	1.29	1.31	1.33	1.35	1.37
Live grading of hogs:—					
Selects	16	15	17	15	14
Thick smooths	4	5	3	5	5
Av. iodine no. of fat	59.3	58.7	56.3	58.0	56.3
Av. refractive index of fat	1.4591	1.4592	1.4589	1.4585	1.4587
Firmness of fat (U.S. Standards)—					
Hard	15	17	19	19	18
Medium hard	5	3	1	1	1
Soft	0	0	0	0	0

It will be noted from Table 1 that while the average iodine number in all lots is safely below 63, the upper limit set for the "hard" grade, certain samples from all groups fell within the range of from 63 to 67. The larger number of what may be regarded as medium hard samples were found in the groups fed the higher percentage of oats. No soft fats were obtained in these experiments.

Proportions of Oats and Wheat in the Ration

During the summer of 1929 an experiment was carried out along similar lines with regard to supplements and management methods as in those conducted during the previous three summers. Wheat was fed in conjunction with oats instead of barley. Feed wheat of from fair to good quality was fed mixed with oats in varying proportions and was also fed as a single concentrate. In addition, the feed wheat was compared with wheat of 3 Northern grade. The data in Table 2 will assist in interpreting the results of this trial.

TABLE 2.—EFFECT OF PROPORTIONS OF OATS AND WHEAT ON FIRMNESS OF FAT

	Lot I Oats 2 F.Wheat 1	Lot II Oats 1 F.Wheat 1	Lot III Oats 1 F.Wheat 2	Lot IV Oats 1 F.Wheat 3	Lot V Feed Wheat	Lot VI No. 3N Wheat
No. of pigs in group	6	7	7	6	7	7
Av. initial wt.	35.8	35.7	35.4	37.7	36.4	37.2
Av. final wt.	205.3	206.6	205.6	204.5	201.4	203.4
Av. daily gain	1.31	1.36	1.38	1.44	1.42	1.38
Live grading of hogs:—						
Selects	3	5	6	3	4	5
Bacons	2	2	1	3	2	2
Butchers (unfinished)	1	0	0	0	1	0
Av. depth of fat on loin (inches)	1.58	1.62	1.64	1.55	1.62	1.54
Av. refractive index of fat	1.4592	1.4588	1.4589	1.4589	1.4588	1.4585
Firmness of fat (U.S. Standards):—						
Hard	5	7	7	7	7	7
Medium hard	1	0	0	0	0	0
Soft	0	0	0	0	0	0

In this experiment a hand grade on the fat was not secured but the refractive index was determined on fat samples secured from each carcass. According to the standards adopted in connection with the American soft pork investigations, only one carcass would be classified as other than "hard". The use of wheat as part or all of the cereal portion of the ration in this trial gave satisfactory results from the standpoint of producing firm carcasses.

Stage of Maturity

In connection with the investigations which Shutt (1) reported in 1901 it was pointed out that the carcasses of pigs slaughtered before maturity or at what would be considered under acceptable market weights, contained a higher percentage of olein than carcasses of mature pigs. Day (2, 3) also refers to the tendency for immature pigs to produce soft carcasses.

This matter has been rather completely investigated in connection with the U.S. soft pork investigations (4) to which reference has already been made. Studies were made of carcasses from pigs slaughtered at different weights. With regard to differences in degree of firmness, the statement is made that "the one outstanding and important fact is the progressive hardening of the pigs as they take on weight and finish. Young weanling pigs are soft (sometimes very soft)—the dividing line between medium soft and medium hard is at about 130 lbs. and that between medium hard and hard at about 170 lbs." This progressive hardening may be explained by the fact that as the pig increases in weight the ratio between fat from food fat and fat from carbohydrates widens.

The relation between market weight or stage of maturity and firmness of the carcass was investigated at the University of Alberta during the summer of 1926. Three groups of pigs of the same breeding, and fed and managed as in the case of the experiment discussed previously, were slaughtered at different final weights. One group was slaughtered at 180 lbs., one at 200 lbs. and one at 225 lbs. These were considered as the only significant weights in a study of this kind since bacon hogs under 180 lbs. and over 230 lbs. were not acceptable for the export trade and were subject to price discrimination on the open market at the time of conducting this experiment. The results of this study are shown in Table 3.

Table 3.—Relation between market weight and firmness of fat

——	Lot I Slaughtered 180 lbs.	Lot II Slaughtered 200 lbs.	Lot III Slaughtered 225 lbs.
No. of pigs in lot	6	6	6
Av. initial wt.	33.8	33.0	34.3
Av. final wt.	183.0	198.5	225.0
Av. daily gain	1.21	1.23	1.29
Av. iodine no.	58.28	60.5	60.03
Firmness of fat (U.S. Standards)—			
Hard	6	5	5
Medium hard	0	1	1
Soft	0	0	0

The results of this work, expressed in terms of iodine numbers, do not indicate any tendency to soft fat at the lower limit of select bacon hog weights nor to any progressive hardening as the weights increase toward the maximum. On the contrary, there is a tendency in this particular case in the direction of a softening as the upper limit is reached. It is apparent, in any case, that the objectionable degree of softness of fat is passed before the 180 lb. stage is reached. In this connection, of course, the matter of lack of depth of back fat and thickness of belly fat in relation to firmness of the carcass must be considered. These features are distinct from the actual softness of the fat.

Percentage Protein in the Ration

During the winter of 1934–35 an experiment involving five groups of eight pigs was conducted with the object of determining the influence of the amount of protein in the ration on carcass quality with particular

reference to percentage of lean and firmness of fat. The pigs were sheltered in colony houses packed on the outside with straw. The grain ration consisted of equal parts by weight of 3 CW oats, 3 CW barley and No. 5N wheat. The protein supplement consisted of tankage 60 lbs., linseed oil meal 20 lbs., alfalfa meal 15 lbs. and salt 5 lbs. in the 100 lbs. The percentage of protein supplement fed to the various groups varied as follows:—

——	Start to 80 lbs. in weight	80 lbs. to 130 lbs.	130 lbs. to 210 lbs.
	%	%	%
Lot I	4	4	4
Lot II	8	8	8
Lot III	12	10	8
Lot IV	16	12	10
Lot V	20	16	12

The results of this trial are shown in Table 4.

TABLE 4.—INFLUENCE OF PROTEIN IN RATION ON FIRMNESS OF FAT

——	Lot I	Lot II	Lot III	Lot IV	Lot V
No. of pigs in group	8	8	8	8	8
Av. initial wt.	47.8	47.8	48.6	47.7	47.9
Av. final wt.	206.6	210.3	215.1	209.7	212.3
Av. daily gain	1.12	1.18	1.29	1.21	1.32
Live grading of hogs:—					
No. selects	5	7	7	7	8
No. bacons	2	1	1	0	0
Hand grading of fat:—					
Firm	6	7	8	7	8
Slightly soft	1	0	0	0	0
Soft	0	1	0	0	0
Av. iodine number	61.2	59.6	62.6	62.8	61.0
Firmness of fat (U.S. Standards)					
Hard	5	7	6	2	7
Medium hard	2	1	2	5	1
Soft	0	0	0	0	0

The results do not indicate any consistent trend with reference to the influence of the amount of protein in the ration on the firmness of fat in the carcass. Since the carcasses were hand graded in this experiment, it is of interest to compare the hand grade with that based on iodine numbers. The tendency in general is toward a higher grading on the physical basis than by the chemical determination. It would seem that the fat samples yielding iodine numbers in the range of from 63 to 67 possess a satisfactory degree of hardness from the mechanical standpoint. While one carcass was graded "slightly soft" and one "soft" by hand grading, there did not appear to be any fat samples giving an iodine number sufficiently high to warrant a classification of "soft."

The Feeding of Frost Damaged Wheat

In view of the prevalent opinion that the feeding of frost damaged grains to pigs tends to produce a relatively soft fat in the carcass, an

experiment was conducted during the winter of 1935–36 in connection with which various grades of frost damaged feed wheats were fed and these compared with wheat of No. 5 Northern grade and with 3 CW barley. The pigs were of similar blood lines and were started on experiment at approximately 10 weeks of age. They were sheltered in straw banked colony houses. Tankage was fed as a protein, mineral supplement at the rate of 8% of the ration.

In lots 2, 3 and 4 individual pigs had to be removed from the experiment before reaching market weight when what appeared to be symptoms of Vitamin A deficiency developed, and in addition two gilts from lot V were retained for breeding purposes. This explains the discrepancy between the number of pigs actually in the groups and the number represented in the fat grading.

In view of the interest in the feeding value of frost damaged wheats, it would seem worth while to submit the results of a chemical analysis of the feeds used in this experiment:—

—	Wheat No. 5N	Wheat Frozen Good Feed	Wheat Frozen Medium Feed	Wheat Frozen Poor Feed	Barley 3CW
Moisture	9.29	9.35	9.08	9.42	13.76
Ash	2.32	1.98	2.25	2.25	2.48
Fat	2.86	2.47	3.08	4.45	2.10
Crude fibre	2.79	2.91	3.70	4.11	6.60
Crude protein	12.76	11.40	13.00	14.93	12.30
Carbohydrates	69.98	71.89	68.89	64.84	6.60
Weight per bushel (lbs.)	58.0	55.5	52.0	48.5	—

A point of special interest in connection with these data is the increase in the proportion of fat in the wheats which were damaged by frost and as the weight per bushel diminished. In view of the close physiological relationship between food fat and the fat in the carcass, this occurrence may be particularly significant.

The results of this experiment are shown in Table 5.

TABLE 5.—THE EFFECT OF FEEDING FROZEN WHEAT ON FIRMNESS OF FAT

—	Lot I Barley (3CW)	Lot II Wheat No. 5N	Lot III Wheat Frozen Good Feed	Lot IV Wheat Frozen Med. Feed	Lot V Wheat Frozen Poor Feed
No. of pigs in lot	8	8	8	8	8
Av. initial wt.	49.2	48.6	48.6	47.8	48.7
Av. final wt.	216.0	205.7	207.7	201.0	204.1
Av. daily gain	1.18	1.14	1.15	1.13	1.13
Av. iodine no. of fat	63.9	65.7	66.4	64.1	65.2
Hand grading of fat:—					
Firm	4	3	3	1	2
Slightly soft	2	1	2	2	2
Soft	2	1	1	2	2
Firmness of fat (U.S. Standards)—					
Hard	3	3	0	2	2
Medium hard	3	1	3	1	1
Soft	2	1	3	2	2

These results show some discrepancy between the hand grading of the fat and the grading based on iodine numbers. However, both systems of grading show a fairly high percentage of fats which are not hard. The fact that soft fats were produced in the groups fed 3 CW barley and No. 5N wheat indicates that the frost damage in itself was not responsible for the condition. Some other explanation must be offered for the unsatisfactory results secured in this experiment. The effect of winter temperature comes in for consideration at this point and will now be discussed.

Effect of Temperature on Firmness of Fat

Among the first to suggest that there might be some connection between the temperature prevailing during the period of development of the pig and the firmness of fat in the carcass, was Friis of Denmark. In a report issued in 1889 (5) he states that all the tests conducted at his station seemed to confirm the theory that the temperature in the hog house was a factor in the production of "first class pork".

Henriques and Hanson (German investigators) in 1901 (6) expressed the opinion that the temperature at which fat was stored might have an effect on the chemical composition of the fat in a pig's body. In an experiment, relative to this point, these men used litter mates fed the same feed under different temperature conditions and secured a deposition of fat on their backs with melting points and iodine number correlated with the external temperature at the time of deposition.

Ewing of the Texas Experiment Station (7) has pointed out that in making soft pork studies on the Fort Worth Texas market it was found that the percentage run of soft hogs ranged from as low as 4% for one week in the latter part of summer to as high as 40% in one week in March 1918, following a severe winter.

It is conceivable in the case of the pig, an animal with practically no natural protection, except a reasonably thin skin, that the temperature under the skin might be lowered during very severe spells of weather under conditions where shelters are inadequate, with a tendency to the deposition of fat of a lower melting point and higher iodine number. The question of increased metabolism for purposes of heat generation during the cold weather introduces the possibility of soft fat being stored by the pig during periods of extremely low temperatures as a matter of self-protection. The softer unsaturated fatty acids would be more readily oxidized, a feature which might have a bearing on physiological processes during very cold weather.

In this connection it is of interest that 150 fat samples from pigs used in summer experiments which have been reported in this paper, show an average iodine number of 58.2, while 72 samples from pigs used in winter experiments show a figure of 63.2. The influence of winter temperatures on firmness of fat would appear to be worthy of further investigation.

Influence of Thrift on Firmness of Fat

It has been suggested by practically all of those who have made a study of the soft bacon problem, that there is a relationship between the thrift of the pig, or state of physiological activity, and the firmness of fat in the carcass after slaughter.

Day (2, 3) mentioned in 1898 that unthrifty hogs are more likely to produce soft bacon than growthy well fed hogs, and Shutt (1) in connection

with his reports explains that apparent irregularities in the matter of "softness" in certain experimental lots may be due to what might be termed "lack of thrift."

Grisdale (8) in discussing the management of bacon hogs states that "pigs that have developed steadily at the rate of say 1 lb. per day are not as likely to give soft pork as others on the same feed that have suffered from indigestion or have been set back in any way."

The writer is of the opinion that thrift is a matter very closely linked up with the soft bacon problem. In this connection it is considered worth while to submit some data from experiments conducted at the University of Alberta during the summers of 1923–24–25. These experiments were conducted with a view to determining the influence of certain rations and methods of feeding on the type of the hog at market weight and on the quality of the carcass from the standpoint of suitability for the export market. Hand grading of fat for firmness was carried out. Samples were not collected for iodine numbers. Table 6 shows the number of hogs in each group, the number of soft carcasses, the average final weight of all hogs in the group and the average final weight of the hogs in each group which yielded soft carcasses.

Table 6.—Relation between rate of gains and soft carcasses

Lot No.	No. of hogs	Av. daily gains (lbs.)	No. of soft carcasses	Av. L.W. of hogs in group at close of experiment	Av. L.W. of hogs yielding soft carcasses
1	21	1.31	0	193.5	—
2	22	1.12	0	193.3	—
3	21	1.32	0	196.5	—
4	21	1.24	1	193.6	191.0
5	21	1.07	5	196.8	197.6
6	21	.98	4	194.3	200.0
7	21	.74	7	192.8	202.4
8	22	.77	9	193.3	204.6

The rations in the last four groups indicated in Table 6 were inadequate from the standpoint of either quality or amount and induced varying degrees of unthriftiness. When the rate of gain fell appreciably below 1 lb. per day in this experiment, the results were very unsatisfactory.

It may be argued that the lower rate of gain should be accompanied by a more complete treatment in the process of fat metabolism, than when the gains are high, but when low gains are the result of a poor state of physiological activity, normal metabolism may be disturbed. It would appear that there may be an optimum rate of gain for the storage of fat of the proper degree of firmness.

Observations of the unthrifty pigs in the experiments referred to suggest that a ration or method of feeding which leads to an unthrifty condition of the pig during the initial or intermediate stages of growth renders him physiologically unable to individualize and synthesize the fats in the feed in such a manner as to develop the necessary degree of firmness in the carcass. The question of unthriftiness in the pig, no matter from

what cause unthriftiness is induced is a physiological problem. There appears to be a disturbance in the process of fat metabolism which has a disturbing effect on normal fat deposition.

Lack of thrift, as this term is understood, may be brought about by improperly balanced rations, scanty rationing, disease and worm infestation and lack of mineral matter and vitamins.

The Influence of Individuality

In the various experiments which have been reported it has been observed that certain inconsistencies in the production of soft fat have occurred. In groups where pigs have been fed alike and have gained at approximately the same rate there have been individual pigs which have yielded fat which showed an iodine number differing markedly from the mean of the group. It seems difficult to explain these marked variations on any other basis than what is commonly referred to as individuality. When litter mate pigs have been distributed in various experimental lots, and the figures showing iodine numbers of the fat samples from their carcasses are grouped together, litter tendencies are rather clearly shown. When this is done with certain litters used in the experiment reported in Table 6, the point is illustrated.

Litter No. 1		Litter No. 2		Litter No. 3	
Pig No.	Iodine No.	Pig No.	Iodine No.	Pig No.	Iodine No.
73	62.6	89	58.6	158	55.6
74	64.1	90	57.5	160	54.6
75	65.2	91	57.5	161	51.9
76	62.3	92	57.3	163	55.5
77	56.1	93	57.7	164	55.4
78	57.6	94	59.2	165	59.2
79	55.8	95	52.9	166	52.0
80	61.6	96	59.9	167	54.9
Mean Iodine No.	60.9		57.5		54.9
Coefficient of Variability	5.63		3.44		3.92

It would appear that the degree of firmness of fat may be an inherent trait such as in the case of the fat content of the milk of individual cows. Selection for an increase in the butterfat content of milk has yielded significant results, and it would seem that selective breeding for firmness of fat in pigs would prove constructive.

SUMMARY

A number of experiments conducted at the University of Alberta over a period of years and dealing with the influence of certain feeds and methods of feeding on the firmness of fat in the bacon hog carcass have been reviewed. The following conclusions are suggested.

1. When pigs were fed skim-milk as a supplement and having access to pasture, changing the proportion of oats and barley in the basal ration

did not materially affect the firmness of fat in the carcass. The iodine number of the fat, however, was reduced as the proportion of oats in the ration was decreased.

2. When wheat was substituted for barley in the ration, there was no deterioration in the quality of the fat in the carcasses. As was the case when barley was fed, as the proportion of oats was reduced the fat tended toward greater firmness.

3. When frost damaged wheat was fed in a winter experiment, a high percentage of soft carcasses were produced, but inasmuch as similar results were secured with wheat of good quality and with barley, it seems apparent that the frost damage per se was not responsible for the condition.

4. Pigs slaughtered at minimum, optimum and maximum live weights yielded carcasses showing a satisfactory degree of firmness of fat.

5. Changes in the protein level of the ration could not be definitely related to differences in the firmness of fat samples.

6. Fat samples secured from pigs fed during the winter months showed higher average iodine numbers than those secured from pigs fed during the summer months. The average iodine number on 150 summer samples was 58.2 and the average on 72 winter samples was 63.2.

7. The condition of "softness" of the carcass was shown to be related to the thrift of the pig and to the rate of growth.

8. Individuality appeared to play a part in the problem of soft fat production. The possibility of selective breeding for firmness of fat in the carcass is suggested.

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Résumé

Une étude des causes du bacon mou. R. D. Sinclair, Université de l'Alberta, Edmonton.

L'auteur passe en revue un certain nombre d'expériences conduites pendant une série d'années à l'Université de l'Alberta et portant sur l'effet exercé par certains a ments et certains modes d'alimentation sur la fermeté de la graisse dans la carcasse du porc à bacon. Les conclusions sont indiquées. Lorsque les porcs recevaient du

lait écrémé en plus de la ration régulière et qu'ils avaient un pâturage à leur disposition, les proportions variables d'avoine et d'orge dans la ration de base n'ont pas beaucoup affecté la fermeté du gras mais l'indice de l'iode dans le gras a baissé à mesure que la proportion d'avoine dans la ration était réduite. Le remplacement de l'orge par du blé dans la ration n'a affecté en rien la qualité de la graisse. A mesure que la proportion d'avoine était réduite, de même que pour l'orge, la graisse devenait plus ferme. Dans un essai d'engraissement en hiver, lorsqu'on a donné du blé qui avait été endommagé par la gelée, on a obtenu un gros pourcentage de carcasses molles, mais comme on a obtenu également des résultats semblables avec du blé de bonne qualité et de l'orge, il semble bien clair que les dégâts causés par la gelée n'étaient pas la cause de cette condition. Les porcs abattus, au poids vif minimum, optimum et maximum, ont donné des carcasses dont la graisse avait un degré satisfaisant de fermeté. Les échantillons de graisse pris sur les porcs engraissés pendant l'hiver accusaient un indice moyen d'iode plus élevé que ceux qui avaient été pris sur les porcs engraissés pendant l'été. L'indice moyen d'iode sur 150 échantillons de graisse, pris sur les porcs engraissés pendant l'été, était de 58.2 et la moyenne de 72 échantillons de graisse, pris sur les porcs engraissés pendant l'hiver, de 63.2. Il a été démontré que la mollesse de la carcasse dépend de la bonne venue ou de la vigueur du porc et de la rapidité de la croissance. L'individualité paraît jouer un rôle dans le problème de la production du lard mou. On arriverait peut-être à assurer la fermeté du lard par un meilleur choix des reproducteurs.

SEED MOTTLING IN SOYBEANS[1]

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Mottling is the term used to describe an abnormal condition in which the seed-coats of yellow- and green-seeded varieties of soybeans become splashed or blotched with irregular brown or black markings. These markings follow no particular pattern. They may vary in extent, in some cases being so small and so faint as to be hardly noticeable while in other cases the colour may not only be heavy and distinct but also so extensive as to cover the entire seed. Seeds with black hilums mottle black while seeds with either brown or colourless hilums mottle brown. The intensity of brown mottling is associated with the colour of the plant pubescence. Where this is tawny the brown colour is much deeper and more intense than where the pubescence is gray.

The cause of mottling has been variously described as due to disease, to hybridization, to environment and to heredity. Where the mottling is inconspicuous and the percentage of seeds affected is small, it may pass almost unnoticed; where the mottling is heavy and the percentage of seeds affected is large, it imparts an unsightly and objectionable appearance. To those unfamiliar with its occurrence mottling may be regarded as indicating impurity of the variety or as an unsoundness of the seed.

The occurrence of seed mottling in soybeans tends to be sporadic. A heavy attack one year may be followed by a light attack or complete absence the following year. Mottling may reappear suddenly after a succession of years of complete freedom from it. There are still many areas in which it has never occurred at all. While certain conditions have been found to favour the production of mottling the exact cause of its occurrence still remains to be determined. It is generally agreed by investigators that environmental and hereditary factors are both partly responsible for its appearance.

REVIEW OF LITERATURE

The investigations of Owen (1) are probably the most extensive that have been conducted into the study of mottling. Rich soils, liberal spacing between plants and shading were among the environmental factors found to be conducive to mottling. Other factors of some importance were inoculation and fertilizers. Difficulty was encountered in distinguishing the influence of heredity from that of environment. It was found possible to select for strains more inclined to mottle than others. The tendency to produce mottling seemed to be more pronounced in varieties with tawny pubescence than those with gray pubescence.

Hollowell (2) found that rich soils, widely spaced plants and shading, tended to increase the amount of mottling as compared with poorer soils, closely spaced plants and absence of shading.

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Piper and Morse (3) after growing different varieties of soybeans side by side in rows and plots for several years noticed certain oddly coloured seeds. This was attributed to the heterozygous condition of such seed brought about by natural crossing. Similar results were later reproduced in the progenies of certain artificial hybrids.

Woodworth and Cole (4) studied the mottling of seeds produced by individual plants. Seeds in the same pods were found to exhibit great similarity in the pattern of the mottling. On growing these seeds neither the parent pattern nor the amount of mottling showed any evidence of being inherited. The causal factors were believed to be physiological rather than genetic.

Woodworth (5) describes further work in the study of mottling in which selection was carried on in non-mottled, lightly mottled, and heavily mottled seeds. He concluded that the selection of individual plants with little or no mottling may be effective in greatly reducing the amount of mottling, and the development of a strain less subject to mottling than the original variety. Recognition was given to the genetic aspects of mottling.

EXPERIMENTAL

Soybean seed has been produced continuously at the Central Experimental Farm, Ottawa, since the year 1928. With one exception the crop was located in a different field each year and a wide variety of soil types was encountered. Mottling made its first appearance in 1933 and occurred again in 1934 and 1935. In 1933, the mottling was heavy and its occurrence uniform throughout the entire field. In 1934, while again very pronounced, mottling was confined largely to fairly definite portions of the field, other parts of the same field being comparatively free from it. As far as could be observed the soil type, which varied from light clay loam to very light sand, had very little influence in determining the area of heavy or light mottling. In 1935, though mottling was present, it was comparatively light throughout the entire area.

Effect of Selection Against Mottling

In order to observe the possible influence of hereditary factors upon seed mottling in soybeans, a number of individual plants were selected in the fall of 1933 from a single short row of the variety, O.A.C. No. 211. The seed of some of these plants showed various degrees of mottling while that of others was entirely free. In 1934, seed from non-mottled, lightly mottled, and heavily mottled plants was sown in progeny rows replicated three times in a randomized arrangement. The test was located on a light, sandy loam soil and it turned out that mottling was very severe in this particular area. The plants were harvested individually but the results obtained are shown grouped together in Table 1.

TABLE 1.—EFFECT OF SELECTION AGAINST SEED MOTTLING IN SOYBEANS OF THE VARIETY, O.A.C. NO. 211 IN 1934

Seed classes	Number of plants harvested	Non-mottled seeded	Mottled seeded
Non-mottled	54	0	54
Lightly mottled	50	0	50
Heavily mottled	52	1	51

Individual plants were not examined separately for the reason that 75% of them in each of the three classes showed some degree of mottling in every seed, most of which was heavy. The remaining 25% of the plants were found to have about 85% of their seeds mottled to a greater or less extent. The degree of mottling was just as heavy and extensive in the seed obtained from the non-mottled and lightly mottled plants as it was in that from the heavily mottled plants. Only the seed of a single plant was entirely free from mottling and, oddly enough, this came from a heavily mottled seed.

From the 54 plants grown from the original non-mottled seed, seed was again selected from those plants which appeared to have the least amount of mottling. Lightly mottled and heavily mottled seeds were also selected from plants grown from the original lightly mottled and heavily mottled selections. This material was planted in 1935 and along with it, the seed which came from the single non-mottled plant shown in Table 1. The results obtained are shown in Table 2.

TABLE 2.—EFFECT OF CONTINUED SELECTION AGAINST SEED MOTTLING IN SOYBEANS OF THE VARIETY, O.A.C. No. 211 IN 1935

Seed classes	Number of plants harvested	Non-mottled seeded	Lightly mottled seeded	Heavily mottled seeded
Non-mottled	36	14	15	7
Lightly mottled	32	9	13	10
Heavily mottled	36	17	12	7
Single plant (non-mottled)	58	18	20	20

It is evident from a comparison of the results presented in Table 2 with those shown in Table 1, that seed mottling was less severe in 1935 than in 1934. In spite of this reduction in the amount of mottling, however, the non-mottled classes again showed no greater freedom from mottled seeds than the lightly and heavily mottled classes. The results for the two years, therefore, are quite comparable and seem to indicate that selection against mottling is not likely to be effective in a variety like O.A.C. No. 211, which possesses a high degree of purity.

Abnormal Plants

Owen (1) made reference to mottling in certain abnormal plants and stated that an accumulation of photo-synthetic products, especially sugars, seems to be the most probable underlying factor responsible for the excessive development of pigment in the seed-coats of the seed from such plants.

Abnormal plants have frequently been observed by the writer in seed multiplication blocks of the Mandarin variety. At the time of maturity, when the normal plants have completely shed their foliage, odd plants have been noticed here and there which continue to retain their leaves in the green or immature condition. Upon examination, the pods of these abnormal plants have invariably been found to be mature, the seed plump and ripe, and the seed-coats mottled, even in the midst of plants the seed

from which showed little or no tendency towards mottling. Since the brown and black pigments have been identified as glucosides, it is easy to conceive, as Owen suggests, that mottling in such plants may be brought about by the continued synthesis of plant foods, after the seed has actually ripened.

Another abnormal type of plant which has sometimes been noticed in Mandarin and other varieties is one in which the pubescence of certain of the seed pods has become either partially or entirely suppressed. Usually the pods towards the tips of the main stem and branches are those principally affected. While the plants mature normally they are easily distinguished because of the dark or discoloured and shiny appearance of these pods. The seed from the affected pods has usually been found to be mottled even when seed from surrounding plants showed no mottling whatever. The pods borne at the lower portion of the main stem and branches of this abnormal type are quite normal with respect to pod colour and pubescence, and the seeds contained in them are usually free from mottling or mottled only slightly. It seems reasonable to conclude therefore, that there is an association between this smooth type of pod and the production of mottling.

Influence of Environment and Heredity in the Production of Mottling in Different Varieties

Some very interesting observations with respect to mottling were made in 1934 in seed harvested from a variety test. Twelve varieties (and selections) were included in the test and each was replicated four times. The replicates of each variety were seeded from a single well mixed sample of seed. The four replicate blocks were arranged in a continuous series in a single range with replicate 1 located at the north end. The range was 27 feet wide and the total of 48 rows in the four replicates extended 120 feet along the range (2½ feet between rows). The total area covered by the entire test was 3,240 square feet—less than one-thirteenth of an acre. The soil type was sandy loam, which was very uniform throughout as shown in the accompanying mechanical analysis.

Mechanical analysis of soil

Soil sample	Sand	Silt	Clay	Amount left on 2mm. sieve
	%	%	%	
Replication 1	70.72	18.93	10.35	5.91
Replication 2	69.26	20.34	10.40	5.96
Replication 3	70.40	19.27	10.33	6.49
Replication 4	68.44	20.21	11.35	4.96

It was not possible to secure a chemical analysis of the soil samples but since the soil as a whole had been handled and cropped in a similar manner for a great many years it is hardly to be expected that the chemical composition would show any marked variation.

Upon completion of the harvest, examination of the seed revealed that mottling had occurred about as follows:—heavy in replicate 1; medium heavy in replicate 2; light in replicate 3; and very light in replicate 4. In other words there was a gradual reduction in the number of mottled seeds from replicate 1 to replicate 4, and all varieties, with few exceptions, were affected alike. Counts were made on 1,000 seeds taken at random from the seed of each of the 48 rows. The number of mottled seeds obtained is shown in Table 3.

TABLE 3.—NUMBER OF MOTTLED SEEDS FOUND IN 1,000 SEEDS OF SOYBEANS TAKEN AT RANDOM FROM EACH OF 4 ROWS OF 12 VARIETIES

Variety	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Total in 4000	Mean
Selection 171	361	357	93	76	887	221.7
Selection 115	479	360	32	59	930	232.5
Selection 95	409	337	127	25	898	224.5
Selection 135	477	364	62	37	940	235.0
Selection 139	463	108	48	14	633	158.2
Selection 49	430	336	56	36	858	214.5
Selection 137	464	64	97	51	676	169.0
Selection 13	408	233	5	32	678	169.5
Manchu (Hudson)	408	70	103	42	623	155.7
Mandarin (Ottawa)	525	207	54	2	788	197.0
"I" Selection	192	50	49	13	304	76.0
O.A.C. No. 211	683	464	162	62	1371	442.7
Total	5,299	2,950	888	449		
Mean	441.6	245.8	74.0	37.4		

A somewhat better picture of the variation in the mottling from replicate to replicate, as well as between the varieties themselves, can be had by reference to Figure 1 which charts the 48 rows in the order in which they were grown.

Statistical treatment of the data contained in Table 3, showed that there were significant differences with respect to both replicates and varieties, which indicates that two separate influences, environment and heredity, were involved; environment being responsible for the differences between the replicates and heredity for the differences between the varieties themselves.

In comparing replicates, differences of 65 or more mottled seeds may be considered significant. While the difference between the means of replicates 3 and 4 fell somewhat short of the required number, both of them were significantly lower in mottling than replicate 2, and replicate 2 had significantly less of mottled seeds than replicate 1. Therefore, even though the area covered by this test was quite small the influence of environment was nevertheless quite definite and very pronounced.

With respect to varieties, differences of 112 or more mottled seeds may be considered significant. "I" selection proved to be quite outstanding having significantly less seed mottling than all varieties except Selections 137, 139, and 13, and Manchu (Hudson). The variety O.A.C. No. 211

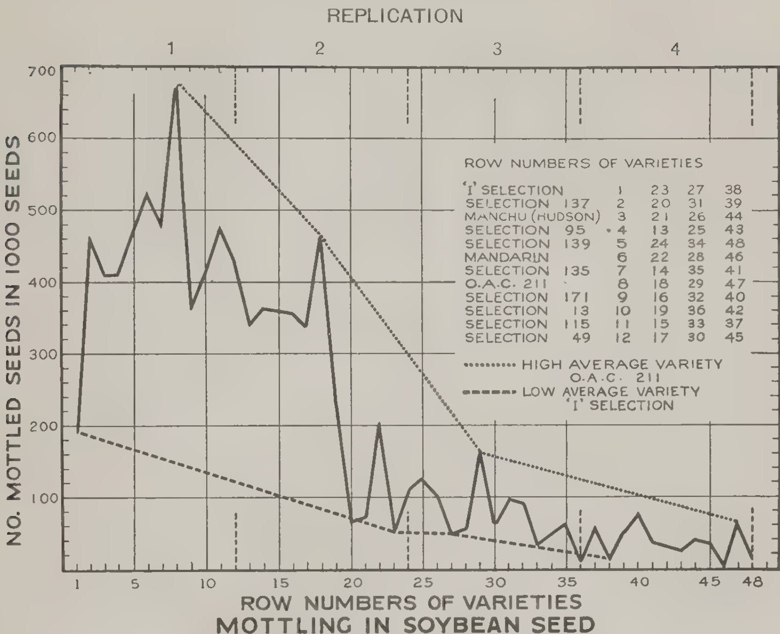

FIGURE 1

showed high susceptibility to mottling and had significantly more mottled seeds than all other varieties. These significant differences between the varieties establishes the fact that heredity as well as environment plays an important role in the mottling of soybean seed.

The apparent hereditary resistance to mottling of the "I" selection was further demonstrated by a number of single plant lines obtained from this strain and grown in a part of the field some distance from that in which the above mentioned variety test was located. As indicated by other rows adjacent to the "I" lines, mottling was quite heavy also in this vicinity. The seed of the "I" lines, however, was practically free from mottling and such as did occur was in the nature of very fine streaks of brown pigment, much less objectionable in appearance than the heavy markings found in the seed harvested from most of the nearby rows.

Some other interesting observations with respect to susceptibility to seed mottling are probably worth mentioning. Five single plant lines selected from the Manchu (Hudson) variety were grown alongside of the "I" lines just described. Upon harvesting, the seed of four of these lines was found to be heavily mottled while the fifth was entirely free from mottling. A distance of 30 inches separated the rows of each of the five lots. A short distance from these rows, but in the same range, a number of single plant lines, originally selected in 1931 from a mixed lot of Manchurian seed, were planted so that two lots occupied a single 27 foot row. A narrow path one foot wide separated these end-to-end rows. In several

instances, while seed from a progeny at one end of a row was mottled considerably, the progeny occupying the opposite end of the same row produced seed which showed no mottling whatever. The behaviour of these lines indicated that certain hereditary influences operated to suppress the appearance of mottling in a number of the selections. All of the lines were originally selected from heterogeneous material. The results here indicate that in working with such material it may be possible to select lines with little susceptibility to mottling. These results are in marked contrast to those obtained from the selection work with the variety, O.A.C. No. 211.

DISCUSSION

While it has been established that environment and heredity both play an important part in the production of mottling in soybean seed, no attempt has been made to determine the actual factors involved.

In the case of the variety test it is apparent that environmental factors were responsible for wide variations in the production of mottled seed. Mottling occurred in spite of the fact that the area covered by the test was quite small and that the soil and other conditions appeared to be uniform. The results obtained in this test indicate that the nutritional or physiological balance between the conditions which either produce or inhibit mottling of the seed must be a very delicate one, especially in those varieties particularly subject to mottling. So far as could be observed the only variant affecting the variety test was a limited amount of shading, caused by buildings, which occurred late in the afternoons of sunny days and which moved quickly across the entire plot from north to south. While shading has been suggested by others as a possible contributing cause of mottling, it is hardly likely that the small amount which occurred in this particular instance could have had much to do with the high degree of mottling produced. Any influence which might have resulted from variation in the spacing was eliminated since all varieties were spaced alike, 3 inches between plants, and the stand at harvest approximated 100 per cent. Plants at the ends of the rows were discarded. Unquestionably freedom of space is responsible for increased mottling as it has frequently been observed by the writer, that plants at the ends of rows produce more mottled seeds and mottle more frequently than plants within the same rows. It is interesting to note that the greatest amount of mottling was produced by a variety with gray pubescence and the least by one having tawny pubescence. Owen (1) found the reverse of this to be true, under certain conditions.

Since the environmental factors which cause mottling are not known precisely, no effective measures to control or avoid it can be advocated in the ordinary growing of soybeans, unless it be in the choice of variety. It has been shown that the effects of environment may be greatly lessened by a strong resistance to mottling which seems to be inherited in certain varieties. The logical procedure at present therefore, would seem to be to concentrate upon the selection of desirable lines which possess this inherited resistance.

Mottling has its basis in heredity. Environment is a secondary cause and is effective only when operating against a favourable hereditary background. If the genes responsible for the black and brown pigments in the

seed-coats were not present or present only in the recessive condition in the genetic make up of the variety, then no pigment could develop and no mottling could occur, irrespective of environmental conditions. The problem appears to be one for the plant breeder to solve.

Woodworth (5) described a cross which he made "between Illini (brown hilum (R_1 r_2)) and a dominant glabrous type (brown hilum (r_1 R_2)). The seeds of the F_1 plant had black hilums (R_1 r_2 r_1 R_2)*. In F_2 of 187 plants, 97 had black hilums, 77 brown hilums and 13 colourless. There was no mottling in this cross to interfere with the separation of colourless from coloured hilums. In this particular type of colourless hilum there is no gene for brown pigment and hence no colour can be produced except plastid pigment, which is yellow or green according to whether the seed-coat is yellow or green."

The problem of producing a strain or strains of the above colourless type, having the double recessive genes for pigment colour, would seem to be a relatively simple one and such strains being incapable of producing mottled seeds should be of considerable practical value, provided, of course, they were equally desirable from other standpoints.

SUMMARY

It is shown that both environment and heredity have a definite influence on mottling in soybean seed.

All varieties tested were found to be more or less subject to mottling.

The selection of strains possessing a high degree of resistance to mottling is suggested as a means for reducing this abnormality.

Theoretically there appears to be no reason why it should not be possible to breed strains which are completely resistant to mottling.

ACKNOWLEDGMENT

Acknowledgment is made to Dr. L. E. Kirk, Dominion Agrostologist, and Dr. L. P. V. Johnson for helpful criticism in the preparation of this paper and to Mr. F. S. Nowosad for making the statistical analysis of the variety test results.

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Résumé

La marbrure de la graine de soja. F. Dimmock, Ferme expérimentale centrale, Ottawa.

Il a été démontré que le milieu et l'hérédité exercent une grande influence sur les taches ou marbrures qui paraissent dans la graine de soja. Toutes les variétés essayées étaient plus ou moins sujettes à la marbrure. Pour réduire cette anomalie, on propose de sélectionner des espèces possédant un haut degré de résistance à la marbrure. Théoriquement parlant il ne paraît y avoir aucune raison s'opposant à la production d'espèces complètement résistantes à la marbrure.

* R_1 and R_2 designate complementary genes for black pigment production in seed-coat and hilum.

A COMPARATIVE STUDY OF SEMI-SCALDING AND DRY-ROUGHING IN RELATION TO THE EASE OF REMOVING PIN FEATHERS BY WAX DRESSING

N. H. Grace[1]

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INTRODUCTION

The development of a method of using wax in poultry plucking necessitated a detailed study of the factors which affect the removal of pin feathers, since this is the main object of wax plucking. The removal of pin feathers by adhesive wax coatings involves two main features. First, it is clear that proper contact between the pin feather and the wax coat is necessary. Second, the actual pull required to remove the pin feather will have a great effect on the efficiency of the operation. This paper gives comparative results (Tables 1–4) showing the effect of the roughing method on both the adhesion of wax to the pin feather and the readiness with which the pin can be pulled from the skin. It is found that dry roughing and semi-scalding exhibit some striking differences in their effect on the pin feathers.

In dressing poultry, it is possible to remove the large feathers directly after sticking, this is commonly called dry-roughing or dry plucking, or to semi-scald the bird and then rough pluck. Semi-scalding consists of immersing the bird in warm water of a definite temperature. For the most part, packing-house practice employs the semi-scald with satisfactory results. It is exceedingly important that the temperature should be most carefully controlled in semi-scalding and this fact renders semi-scalding of doubtful practicability to a very large percentage of the small dressers of poultry. Bearing in mind the limitations of the average poultry farmer as to equipment and necessary technique for controlling the operation of semi-scalding, efforts were made to develop a wax mixture suitable for use with dry-roughed birds. The results reported (1, 2), have been most satisfactory with one or two exceptions. In certain special cases, semi-scalding is required for a perfect plucking job. While some of the reasons for this fact have been given (1, 2) more detailed information is provided in this paper.

Important Features of Semi-Scalding

The operation of semi-scalding is fairly well known; it has been fully discussed in connection with wax-plucking (1, 2). However, certain aspects may be singled out for special attention.

(a) *Temperature of Water*

For fowl, the water temperature should be close to 130° F.; slightly lower temperatures are desirable for chickens and broilers. A series of experiments were carried out in which temperature changes of the skin were followed by means of a copper-Constantin thermocouple placed under

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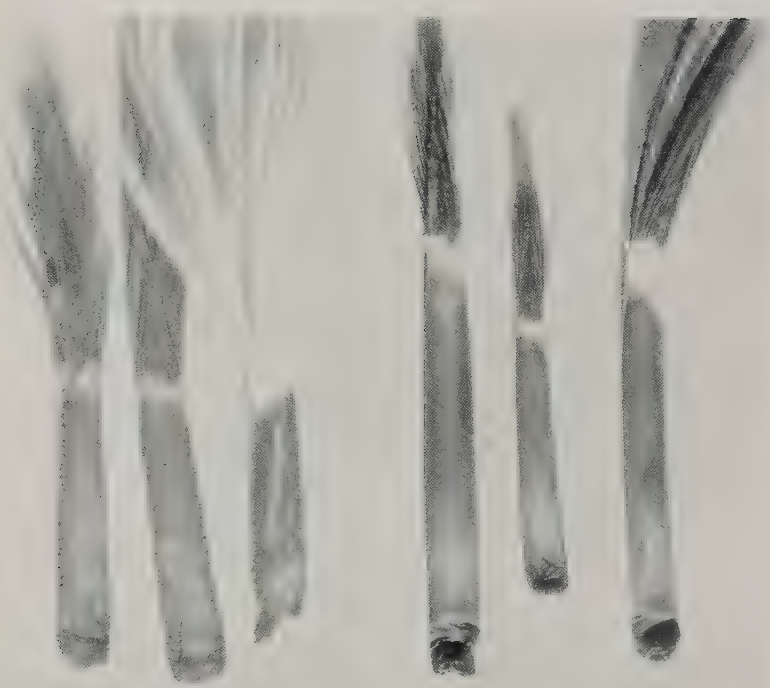
Figure 1



A. Dry-roughed pin feathers. B. Semi-scalded pin feathers.

the skin. It was found that a steady temperature was attained in approximately 30 seconds. If the water temperature is a degree or two low, feather and pin feather loosening is poor. Higher temperatures, on the other hand, will cause damage to the skin and adversely affect the bloom of the carcass. The effect of high temperature is particularly noticeable in the case of broilers with their exceedingly tender skin.

(b) *Agitation of Water*

Effective agitation of the water used for semi-scalding is carried out in commercial plants by mechanical means. Proper agitation ensures adequate penetration of warm water to the roots of pins and feathers and will allow a shorter immersion period. In the case of hand dipping, manual agitation is effective with immersion periods of about one minute. It is well to recognize that semi-scalding is essentially dependent on heat transfer from water to skin; agitation permits efficient penetration through the insulating mass of feathers.

(c) *Semi-scalding and Bleeding*

This phase of the dressing operation requires experimental study. It may be mentioned, however, that experienced buyers of dressed poultry hold the view that adequate time should be provided for bleeding before semi-scalding. The product from poultry dressing plants in which there is a short moving track between the killer and the semi-scalding tank is inferior in appearance to that from plants with greater trackage. Some of the birds are off-coloured, owing to partial inhibition of bleeding by the too brief interval between killing and immersion in warm water. Poultry plants in which there is a considerable distance of track between killer and scalding tank have noticeable freedom from this trouble. The minimum time required for efficient bleeding remains to be determined, but pending this it is probably advisable to bear in mind possible deleterious effects of insufficient time for bleeding before semi-scalding. This is of special importance to organizations which intend to install efficient waxing machinery.

Factors which Affect the Contact of Wax and Pin

It is obvious that effective removal of pin feathers by wax depends to a great extent on the contact between feathers and wax. For instance, it was found that in addition to the actual strength of a given wax its adhesion to the quill surface is of great importance. It has already been pointed out (1, 2) that semi-scalding is desirable in the case of certain types of pinny birds. Pin feathers, particularly in certain stages of development, tend to have a scaly surface. This loose shell prevents contact between the wax and the quill surface. On pulling the wax, the scale lifts off, the feather tuft is removed and the hollow quill remains in the carcass. Semi-scalding tends to remove this loose scale, thus promoting better contact between the pin surface and the wax coat. In consequence, an improved plucking job results, particularly in the case of short pins from which the feather tufts are just sprouting.

Figure 1 shows moderate magnifications of semi-scalded (B) and dry-roughed (A) pins. The rough, scaly surface of the dry-roughed pins is readily noted and it is clear that the semi-scald presents an improved

surface to which the wax can adhere. It is not at all surprising that broilers and birds with short, immature pins are cleaned more satisfactorily by wax after semi-scalding.

It may be of interest to point out that pin feathers of the duck fail to respond to semi-scalding. Observation fails to indicate any difference in duck pin feathers before and after semi-scalding. Incidentally, wax dressing does an excellent job with ducks after dry roughing except in the case of young birds with numerous extremely short pin feathers. A few experiments on the waxing of this type of duck were carried out. The duck pin is comparatively oily, and this probably reduces the strength of the bond formed between the quill surface and the wax. An effort was made to reduce the oil content of the surface by semi-scalding in water to which sodium carbonate or sodium phosphate had been added. A slight improvement in the operation was noted; however, the results are not very satisfactory. To date, investigation has not revealed a way in which young exceedingly pinny ducklings can be successfully plucked by the use of wax.

The Force Required to Remove Pin Feathers

While the bond between the wax coat and the pin is of great importance, it is clear that the actual pull required to remove the pin will have an important bearing on the results. In consequence, a brief study has been made of the magnitude of the pull necessary to remove individual pin feathers. A comparison of semi-scalding and dry-roughing is of particular interest; the effect of the length of time intervening between killing and waxing is also important.

Certain difficulties are apparent in determining the force necessary to pull out an individual pin feather. Not only is there a great difference in the size of pins, but the maturity of the pin feather, the condition of the bird, possibly the breed, the situation of the pin in the bird and the method of measurement are all factors which have a bearing. In spite of these difficulties, average values from a number of different pins on similar birds do give results which are approximately reproducible.

EXPERIMENTAL

The experimental equipment consists of a laboratory trip-balance placed on a stand. To one side a small spring clamp is attached. The system is balanced by means of the adjustable weight and pointer. A beaker is balanced on each pan. The clamp is attached to a pin and the height of the balance is adjusted in such a way that there will be approximately uniform initial tension, and water is poured into one beaker. The rate of water addition is comparable in each case and the pull is recorded as the number of cubic centimetres of water which must be added to remove the pin.

In each case, pin feathers are taken from the side, back, breast and leg. The number of pins taken will vary somewhat with the number available—in the case of readings at different times there may be none too many on the bird unless it is exceedingly pinny. However, from 8 to 12 pins were pulled for each average value recorded.

Results

Two birds of a given lot are considered; one is semi-scalded, the other dry-roughed. The pull required to remove the pins is determined and the average value is recorded as grams per pin. The results in Table 1 were obtained one and one-half hours after killing; the bird was hanging in the laboratory during this time and the room temperature was around 72° F.

TABLE 1.—PULL REQUIRED TO REMOVE PIN FEATHERS (gm. per pin)[2]

	Dry-roughed Pins	Semi-scalded Pins
Average	121	85

The above is repeated at a later date with two birds from a different lot.

TABLE 2.—PULL REQUIRED TO REMOVE PIN FEATHERS (gm. per pin)

	Dry-roughed Pins	Semi-scalded Pins
Average	99.9	75

The following results include the effect of variations in the time between killing and removing the pins (in all cases, the birds are held at the laboratory temperature of about 72° F.). It is of interest to determine the effect of time on the pull, since waxing technique, particularly for dry-roughed birds, requires a time interval of from 1 to 3 hours between plucking and waxing in order to ensure that the wax will not smear the carcass. All the birds in this section are from the same lot and they were killed within a period of a few days.

The results are averages from determinations on two different birds.

Table 4 gives the values for the average pull per pin on each of two dry-roughed birds. This gives, then, some indication of the variations which are encountered in making the determinations.

TABLE 3.—PULL TO REMOVE PINS AT DIFFERENT INTERVALS AFTER KILLING

Time between killing and pulling	Dry-roughed (gm. per pin)	Semi-scalded (gm. per pin)
$\frac{1}{4}$ hour	108	86
$\frac{1}{2}$ hour	125	83
1 hour	124	85
$3\frac{1}{2}$ hours	118	69

TABLE 4.—PULL REQUIRED TO REMOVE PINS FROM DRY-ROUGHED FOWL

Time betteen killing and pulling	Bird 1 (gm. per pin)	Bird 2 (gm. per pin)
$\frac{1}{4}$ hour	116	100
$\frac{1}{2}$ hour	118	132
1 hour	126	122
$3\frac{1}{2}$ hours	115	121

Discussion

The striking feature is the loosening effected by semi-scalding. It is very definitely easier to remove pin feathers following the semi-scald; there is an actual loosening of the pin due to the action of warm water. The pull

[2] These and the following results were obtained with Leghorn fowl.

required to remove pins after semi-scalding is about two-thirds that for similar pins following dry-roughing.

It is interesting to note that there is little change in the pull required to remove pins up to one hour after killing—it is usual for semi-scalded birds to be waxed in about one hour, providing that suitable drying facilities are available. As the interval between killing and waxing is lengthened to around three hours, there is a decrease in the force required to remove semi-scalded pins. This decrease is indicated in the case of dry plucked birds also, but is quite small. It may be concluded that the usual time allowed for cooling before the waxing of dry-plucked birds will have little effect on the ease of pulling the pins. It is possible that there is a decrease in the tendency for hollow quills to remain when several hours intervene between killing and waxing dry-roughed birds; this feature has not been considered quantitatively. Several factors are involved in the increased ease of removal of pin feathers a few hours after killing. The stiffening of the muscles and physico-chemical changes associated with death are undoubtedly responsible. Under ordinary conditions, the skin temperature approximates that of the room in which the bird is held after one to one and one-half hours. While wide variations in temperature may have some effect, this has not been considered. It has been found that long hanging of birds, for instance, over night, before waxing seems to increase the ease of removing the pins. While quantitative measurements have not been made, it appears probable in the light of results obtained after three and one-half hours hanging. As a matter of fact, hanging over-night prior to waxing is not to be recommended, particularly in the case of semi-scalded birds, as there is greatly increased danger of damaging the skin and affecting the bloom of the carcass. This phase of the problem is merely of academic interest, as the dressing operation should be completed as soon as possible.

It must be pointed out that these measurements were made in order that a clearer knowledge of inherent differences in semi-scalding and dry-roughing should be available. The results themselves, while comparable and valuable, in that they indicate real differences, cannot be considered as extremely accurate or as covering a very wide field. It is doubtful whether a more intensive study would be warranted as the present data seem quite adequate.

SUMMARY

Semi-scalding and dry-roughing of poultry before waxing have been compared. It has been shown that semi-scalding removes most of the scale which prevents good contact of wax to quill in some cases, and thereby promotes a better wax-to-pin-feather bond, with greatly improved plucking. However, this is not the only action of the semi-scald as it actually loosens the pin feather and permits its removal with one-third less force than that required following dry-roughing. If the bird is waxed within an hour of killing, there is little variation in the force required to remove the pin. With longer times between killing and waxing there is a slight decrease in the pull required; this is particularly noticeable in the case of semi-scalded pins.

In view of this two-fold action of the semi-scald in increasing the ease of removing the pins, it is not surprising that special difficulties were encountered in developing a wax and method of use suitable for dry-plucked birds.

Finally, it must be emphasized that the semi-scalding of birds which would otherwise gave poor results on wax dressing is an exact operation. Temperature control is exceedingly important.

REFERENCES

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Résumé

Une étude comparative de l'échaudage et du dégrossissage à sec pour faciliter l'enlèvement des petites plumes par le cirage. N. H. Grace, Laboratoires de recherches nationales, Ottawa, Canada.

Une comparaison de l'échaudage et du dégrossissage à sec des volailles avant le cirage a été faite. On a constaté que l'échaudage enlève presque toutes les écailles qui, dans certains cas, empêchent la cire de bien adhérer aux tuyaux de plumes, et cette adhésion plus solide entre la cire et les petites plumes améliore beaucoup la plumaison. Ce n'est pas là cependant le seul avantage de l'échaudage. Il dégage aussi les petites plumes, facilitant ainsi leur arrachage; il faut en effet un tiers de force de moins pour cet arrachage après l'échaudage qu'après le dégrossissage à sec. Si l'oiseau est ciré moins d'une heure après l'abatage, il y a peu de variation dans la force requise pour éplucher. Lorsque le délai entre l'abatage et le cirage est plus long, il faut un peu moins de force pour arracher les petites plumes. Ceci se remarque spécialement dans les plumes échaudées. Etant donné le fait que l'échaudage facilite de deux façons l'enlèvement des plumes, il n'est pas étonnant que l'on ait éprouvé des difficultés spéciales à développer une cire et un mode d'emploi convenables pour les oiseaux épluchés à sec. Enfin, rappelons également que l'échaudage des oiseaux est une opération qui exige de la précision. Le contrôle de la température est extrêmement important.

BOOK REVIEW

Feeds and Feeding, Twentieth Edition. Henry Morrison. The Morrison Publishing Company, Ithaca, New York. Price $5.00.

Morrison's "Feeds and Feeding" needs no introduction to the Canadian livestock fraternity who have long recognized the value of this handbook, and so it requires little more than to announce that the 20th edition of "Feeds and Feeding" is now available for distribution to ensure its prompt appearance in the libraries of both student and feeder.

To include the latest information on animal feeding and nutrition, the book has been entirely rewritten, and considerably enlarged. A new chapter on proteins, minerals and vitamins is an addition of importance, while another added feature is the set of questions following each chapter.

Considerable improvement has been effected in this book as a text by the rearrangement of certain material. The references, for example previously appearing as abbreviated footnotes on the page, have, for each chapter, been collected and given in one block following the set of review questions. Of greater importance, however, is the rearrangement and consolidation of the tables of average composition of American Feeding Stuffs, Digestible Nutrients, and Digestion Coefficients. These data, which previously occupied three separate tables, are now presented in one, thus bringing together in one place all this information for a given feed. Furthermore, those feeds which vary considerably from sample to sample according to geographical source, varietal difference, or by reason of recognized and standard methods of preparation have been sub-grouped to show these differences. In addition, the figures have been revised in the light of recent analyses. Where the newer figures were markedly different from those previously used, the latter have been discarded. Otherwise, the recent data have been averaged in with the original figures.

A change of fundamental importance is the revision of the Morrison Feeding Standards to conform to the findings in this field during the past ten years. These have not only been changed as to amounts but also as to arrangement. Protein requirements have been altered and the total digestible nutrients calculated proportional to surface area of animal rather than live weight. Hence, instead of indicating the nutrients per 1,000 pounds live weight of animal, the standards are expressed in terms of *requirements per head daily*, and calculated for the various weight groups. This has considerably enlarged the table but has at the same time eliminated much of the calculation previously necessary in using the standards.

The extensive table of mineral composition of feeds and the one indicating their probable vitamin contents will also be very useful.

As a reference for the student, this book is undoubtedly the most complete in its feld. As a handbook for the feeder, it will answer more questions than any other single guide. Quite naturally, it has been written from the standpoint of the American stockman. Its specific recommendations, therefore must be considered by the Canadian reader with this fact in mind, and allowance made where market requirements or other factors peculiar to Canadian conditions are sufficiently different from those in the United States to influence relative feed values and acceptable feeding and management practices.

E. W. Crampton.